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DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE
DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U)
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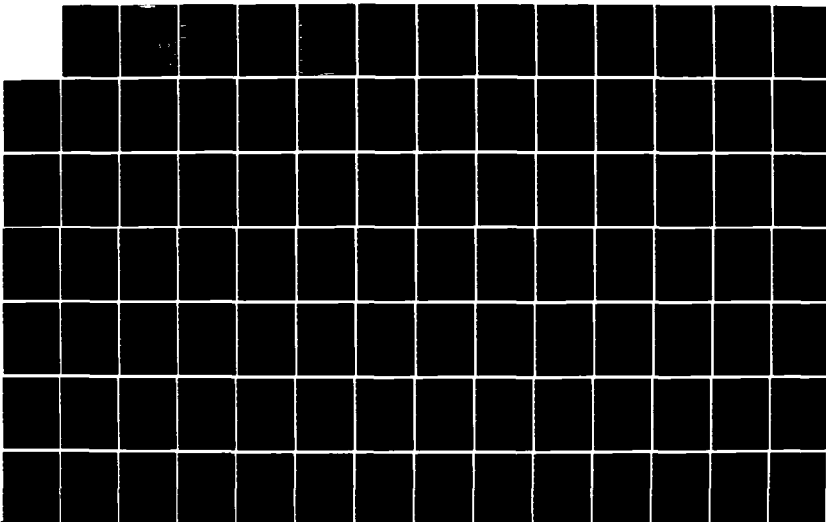
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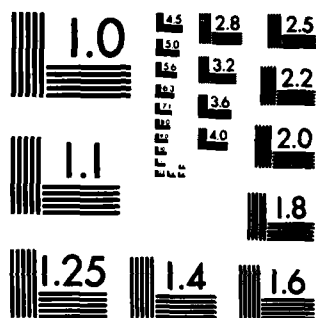
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DEVELOPMENT OF A
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(UNABRIDGED REPORT)

April, 1976

Prepared for

Department of the Navy
Naval Ship Engineering Center
Center Building
Prince George's Center
Hyattsville, Maryland
Code 61648

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By

M. Rosenblatt & Son, Inc.
Naval Architects and Marine Engineers
New York, New York

Under

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Abstract

↳ A method of calculating the resistance of a ship being towed is necessary in order to calculate the maximum allowable towing speed for a given tow and towline and the loads for the sizing of the towing gear. To develop such a method, available methods of calculating hull, locked propeller and wind resistance and added resistance in waves of a tow were investigated. With results of the investigation of these four resistance components, a new step by step calculation procedure for determining tow resistance was developed. A correlation study was conducted to compare the results obtained using the new procedure with the method currently used by the U.S. Navy and with data obtained from full scale tests. General conclusions are reached as to the accuracy and applicability of the new method for determining tow resistance developed in this report. Recommendations are made for future research and development.

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APPENDICES

Appendix A	Hull Resistance Calculations
Appendix B	Locked Propeller Drag Study
Appendix C	Calculations for Added Resistance in Waves
Appendix D	Development of Data Table for Characteristics of Naval Vessels
Appendix E	Correlation Study

1. INTRODUCTION

This is the final report on the subject of the development of a calculation procedure for the determination of tow resistance, NAVSEC contract number N00024-75-C-5508, task number 6140-808.

This task originated from the need for a better method of calculating the resistance of a ship or barge under tow. The calculation procedure must be simple enough for a ship operator to quickly calculate the tow resistance while towing yet be sufficiently accurate for sizing towing gear and for determination of the maximum tow speed. The method currently employed by the U.S. Navy to calculate tow resistance may be found in the U.S. Navy Towing Manual, NAVSHIPS report number 0925-000-1000 which was published in 1971. The basic approach was to calculate hull resistance for a wide range of naval ship classes and to re-examine and if possible verify the calculation of propeller, wind and sea state resistance. Sufficient documentation was presented so the proposed procedure for calculating tow resistance would be amendable for future development.

The specific task requirements were as follows:

- 1) Calculate hull resistance for tow speeds from 0-12 knots for a wide range of naval ship classes.
- 2) Investigate the available calculation methods for determining locked propeller resistance.
- 3) Develop a method for determining the added resistance due to waves for the range of Beaufort numbers from zero to seven.
- 4) Investigate the available procedures for calculating wind resistance and improve the present procedure if possible.
- 5) Prepare a format for the presentation of the data and the calculation procedure developed by MR&S in this study.

- 6) Perform a correlation study to compare results obtained from full scale towing tests at sea with the results obtained from the U.S. Navy towing manual and the MR&S proposed method.

Section 2 presents considerations in the determination of tow resistance to provide an overall view of the towing problem, describe the basic assumptions made in the formulation of a calculation procedure, and state the limitations involved in the use of the calculation procedure. The importance of problems related to towing not considered in the development of a calculation procedure for tow resistance is discussed.

Sections 3, 4, 5 and 6 treat the rationale for the development of the major tow resistance components, hull, propeller sea state and wind resistance respectively. Each section discusses the problems of determination, methods of determination, presentation of results and accuracy of results.

Section 7 combines the material of the previous sections into a step by step calculation procedure for determining tow resistance. It also includes the data necessary for performing resistance calculations for the complete range of naval ship classes.

Section 8 presents a correlation study which compares results from the calculation procedure of the U.S. Navy Towing Manual with results from the MR&S procedure (Section 7) with respect to the four major resistance components. Results of full scale towing tests of the LST 1179 class were also compared with the two methods of calculation above.

Sections 8 and 9 contain conclusions and recommendations for future research and development.

2. THEORY OF TOWING

The determination of tow resistance is really a three-dimensional problem since the tow, towing ship and towline are not usually in the same plane. However, this study restricts itself to a two-dimensional problem by assuming that the tow follows directly behind the towing ship with zero yaw and only the resistance of the towed ship at that end of the towline is considered. Towline drag is not treated in this report.

Four basic components of tow resistance are considered in this report:

- (1) Hull resistance which is composed of frictional and residuary resistance with an allowance for hull roughness.
- (2) Locked propeller resistance which for certain ship types may be three times greater than the hull resistance.
- (3) Added resistance due to waves which can become a significant component when towing is conducted in higher sea states.
- (4) Wind resistance, which is always present due to the velocity of the tow, may be a significant component at high wind speeds.

These four tow resistance components are further discussed in the following sections and Section 7 combines these components in a calculation procedure to determine the tow resistance.

In conducting a rigorous analysis of the towing system other factors in addition to the four components above should be considered. As mentioned before the towline hydrodynamic drag must be considered in the calculation of the towline loading.

The tow resistance itself will be larger if all six degrees of motion are considered. The sea state resistance as developed, considers the added

R_{α} = resistance at same heading angle lb.

α = heading angle in degrees

Average values for C_W for various naval ship types are for carriers 0.45 (CV 9 and CVE 55), for combatant types 0.70 (CA 139, CL 145, DD 445, DD 692, LST 1156), for cargo ships 0.75 in design condition, and 0.90 for the light condition (Ref. 13, 14).

Curves for average values of K for tankers, cargo ships and combatant types have been constructed (see figures 5-1 to 5-3). To allow some margin of resistance for drift multiply K by 1.5.

Combining the conversion constant for tow speed, $p/2$ and the factor of 1.5 yields the equation for wind resistance.

$$R_W = 0.00506 C_W A_T K V_R^2$$

where V_R is tow speed in knots.

The advantages of this method over the other methods aside from simplicity is the use of drag coefficients developed specifically for naval ships, a method for accounting for heading angle and use of data which is available for most all U.S. naval ship classes. Uniform gradient is implicitly assumed which adds a progressively larger factor to safety as wind speed increases.

5.3 Accuracy of Results

It is expected that the above method will generally yield conservative results. The greatest error will probably result from the inaccuracy of the assumption for drift and the determination of wind

velocity at sea. The wind resistance will generally be less than 12% of the tow resistance so extreme accuracy is not required when compared with the other resistance components.

6. Sea State Resistance

6.1 Problem of Determination

The determination of a "simple" method of calculation to apply to all naval ship classes in all sea conditions is the most difficult problem of this study. Unfortunately sea state can be a significant factor for the tow resistance calculation at higher wind speeds as indicated in Table 6-1 (Ref. 20). The percentages in the table will be greater

Table 6-1. Percentages of Total Ship Resistance With Weather Head On (From Ref. 20)

Wind speed, knots	30	40	50	60	70
Hull resistance in smooth water	56	46	36	28	21
Extra hull resistance in rough water	33	36	37	36	31
Wind resistance	10	16	24	32	39
Rudder resistance	1	2	3	4	6

than those for a towed ship due to the addition of locked propeller resistance. At the present time, a sea state factor, K_1 is used in the U.S. Navy Towing Manual (Ref.8). This K_1 factor is multiplied by the calm water resistance of the hull and locked propeller to yield the tow resistance in a sea state (without wind). No documentation of the development of this K_1 factor was available, so it is not known why the propeller resistance should be involved in a correction for sea state. The K_1 factor is presented in Table 6-2.

The MR&S study separates the hull and propeller resistance and corrects only the hull resistance for sea state. In this method, the added resistance in waves is added to the calm water hull resistance instead of using it as a percentage factor since the added resistance in waves is independent of

the calm water resistance (Ref. 27).

WIND FORCE (BEAUFORT SCALE)	WIND VELOCITY (KNOTS)	AVERAGE WAVE LENGTH DUE TO WIND (FEET) ¹	PROBABLE MAXIMUM WAVE HEIGHT (FEET) ²	TOWING FACTOR K ₁
0	0 - 1	--	--	1.0
1	1 - 3	25	--	1.1
2	4 - 6	52	1.7	1.2
3	7 - 10	84	3.4	1.3
4	11 - 16	124	7.9	1.4
5	17 - 21	179	13.2	1.5
6	22 - 27	243	19.7	1.6
7	28 - 33	317	27.1	1.7
8	34 - 40	421	36.5	1.8
9	41 - 47	572	(2)	2.0
10	48 - 55	827	(2)	2.2
11	56 - 63	--	(2)	2.5
12 - 17	64 - 118	--	(2)	2.8

Table 6-2. Towing Factor K₁ from U.S.N. Towing Manual (Ref.8)

Three basic approaches are used here in the development of a correction for sea state: 1) use of full scale data taken at sea, 2) use of approximate methods for calculating added resistance for a stationary ship, and 3) use of an analytical method which uses the principal characteristics of Series 60 hulls and the Pierson Moskowitz sea spectrum. It was beyond the scope of this task to perform an exhaustive literature survey for these approaches, but a few sources were examined to obtain up to date methods of predicting added resistance in waves.

Very few full scale tests for added resistance in waves have been conducted and the data collected is generally for small low powered ships.

Bonebakker collected powering data for hundreds of observations of a low powered motor tanker over a range of weather conditions. Figure 6-1 shows a plot of percentage increase in power in waves versus Beaufort number and Table 6-3 gives the ship particulars for the motor tanker (Ref. 20).

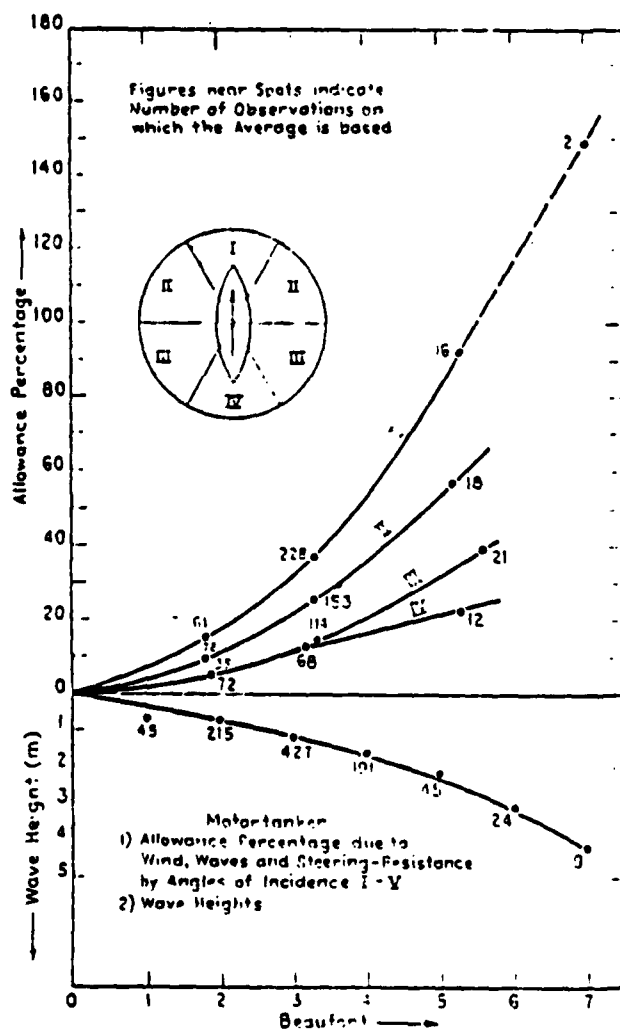


Table 6-3. Particulars of the Ship Investigated by Bonebakker (1954)

	Motor tanker
<i>Hull</i>	
<i>L</i> (h pp)	148.74 m = 487' 8"
<i>L</i> (on lwl)	152.31
<i>B</i>	22.25
Draught	8.57
Displacement	21,111 m ³
Block coefficient	0.744
<i>Propeller</i>	
<i>D</i> (diameter)	5.75 m
<i>P</i> (pitch)	4.68
<i>P</i> (0.7 R)	4.415
<i>P</i> (hub)	3.25
<i>P</i> (virtual)	4.80
Number of blades	4
<i>F_{all}F</i>	0.40
Speed, designed	12.5 knots
<i>V</i> / $\sqrt{L/g}$	0.565
1. Model regression equation	$dA_p / (0.1N)^{1/2} = 0.041 \pm 4.50$
2. Ship trial regression equation	$dA_p / (0.1N)^{1/2} = 0.0562 \pm 4.388$
3. Mean service regression equation	$dA_p / (0.1N)^{1/2} = 0.019 \pm 4.31$

Fig. 6-1. Increase of shaft horsepower in rough weather (from Bonebakker, 1954)

Note that the allowance percentage of Figure 6-1 includes wind and steering resistance along with the resistance due to waves. No direct comparison be made with Table 6-2 since the K_1 values of Table 6-2 are multiplied by the sum of the hull and locked propeller resistance.

Figure 6-2 provides a curve showing the percent increase of power for the ship Lukuga again considering both wind and waves combined for head seas versus the Beaufort scale (Ref.16).

Table 6-4 gives the ship particulars of the Lukuga and Figure 6-3 shows the contribution of wind and waves to the total increase of resistance in adverse weather.

Ship's name	m.v. Lukuga
Shipowners	Compagnie Maritime Belge
Shipbuilders	Cockerill-Ougrée
Hull condition	Shell welded, frames riveted
Length between perpendiculars Lpp, meter	136,000
Breadth moulded Bm, meter	18,700
Depth to upperdeck (deck C) C, meter	12,000
Draught heavy-loaded condition, meter	Fore 8,630 Aft 8,945
Draught light-loaded condition, meter	Fore 4,935 Aft 6,555
Deadweight, tons	11,000
Service speed, knots	16

Table 6-4

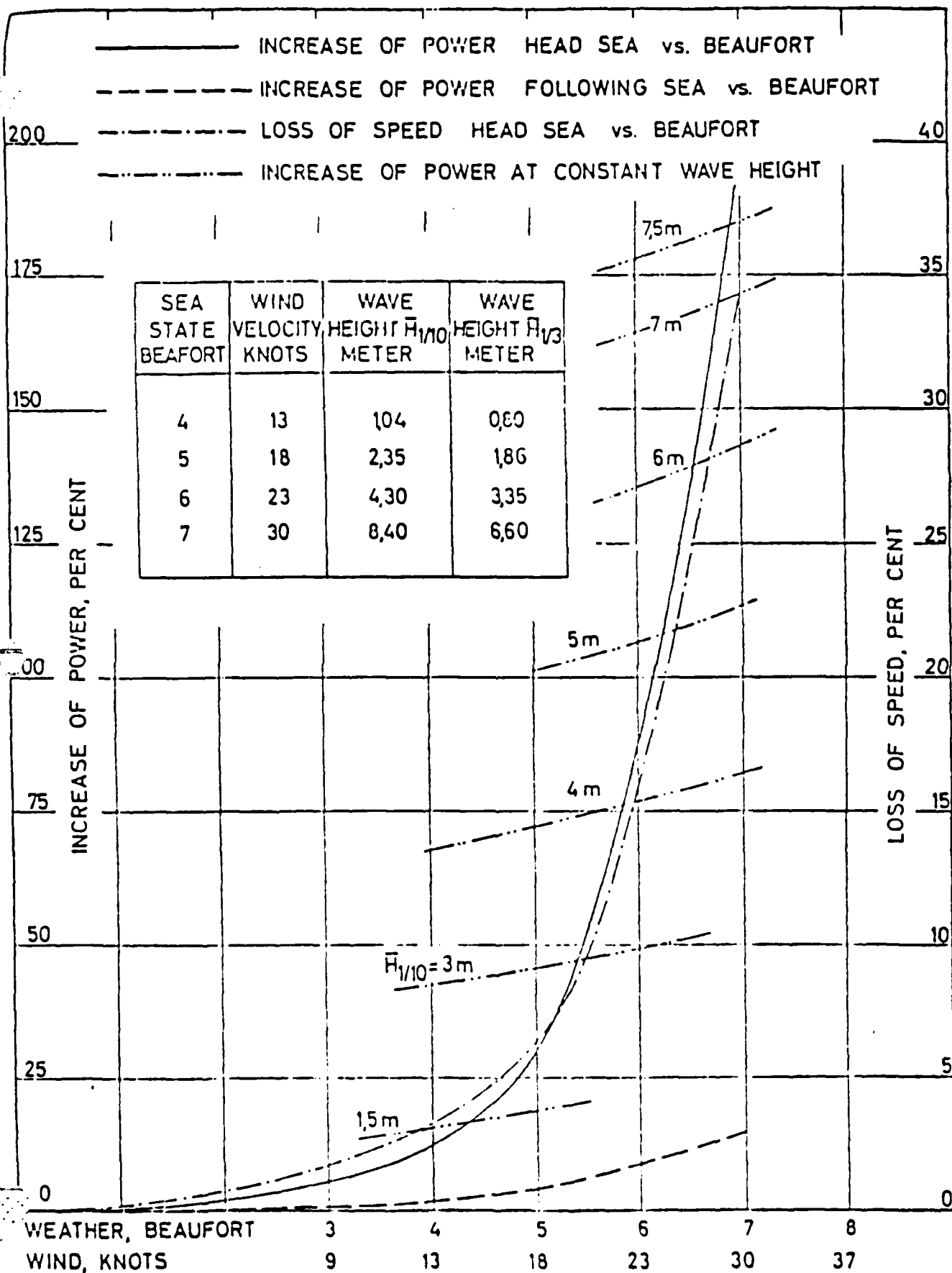


Figure 6-2 (Ref. 16)

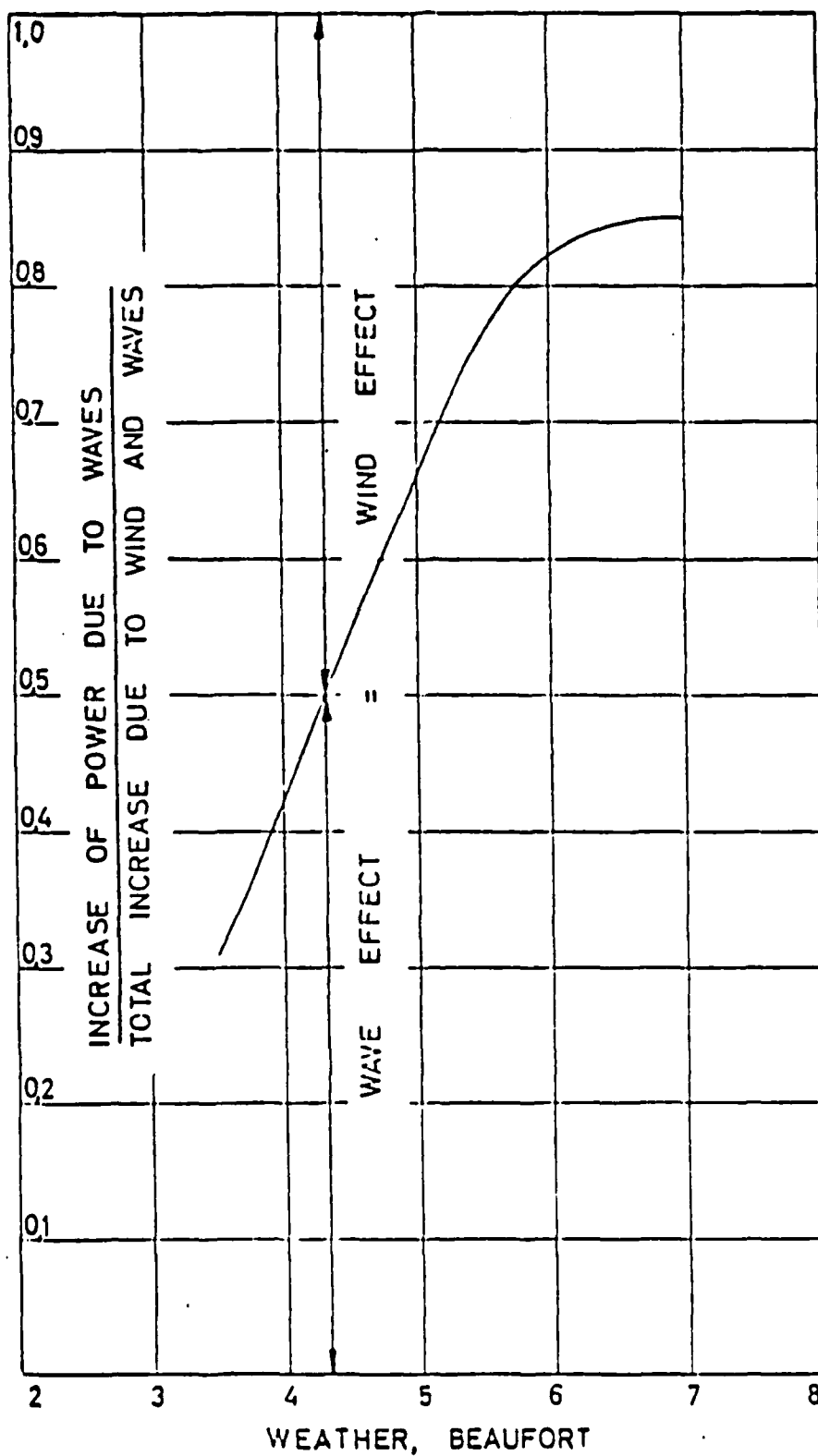


Figure 6-3 (Ref. 16)

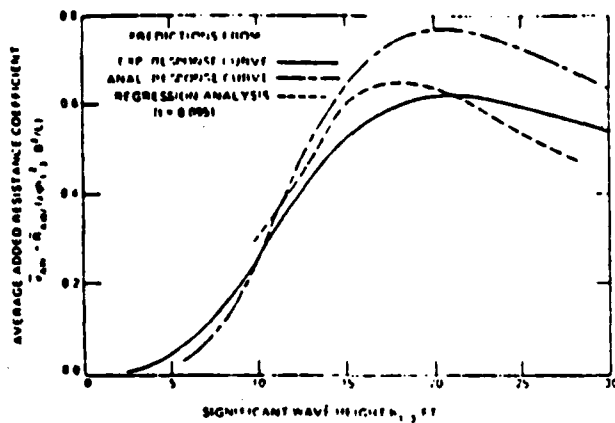
The problem with the full scale experiments discussed is that they apply only to two ships for very limited sea spectra. It is known that the added resistance in waves is dependent on the ship characteristics and the particular environment or sea conditions the ship is operating in. Thus the above methods alone are inadequate for establishing a single criteria for correcting the hull resistance for waves.

Another problem is that the delivered horsepower is a function of the quasi-propulsive coefficient and ship speed in addition to ship resistance. The delivered horsepower invariably increases faster than resistance if ship speed is maintained constant as the ship encounters waves. This results from the increased propeller thrust which leads to an increase of the propeller thrust loading coefficient and a decrease of propeller efficiency. Thus the quasi-propulsive coefficient decreases and the delivered horsepower increases. It is generally assumed that the thrust deduction and wake fraction are not greatly effected by waves (Ref. 20). In the tests shown in figures 6-1 and 6-2 the speed was reduced somewhat as the ship encountered higher Beaufort numbers to avoid damage from slamming. Because of these problems the plots of percent increase of power versus Beaufort number do not directly indicate the percent increase of resistance.

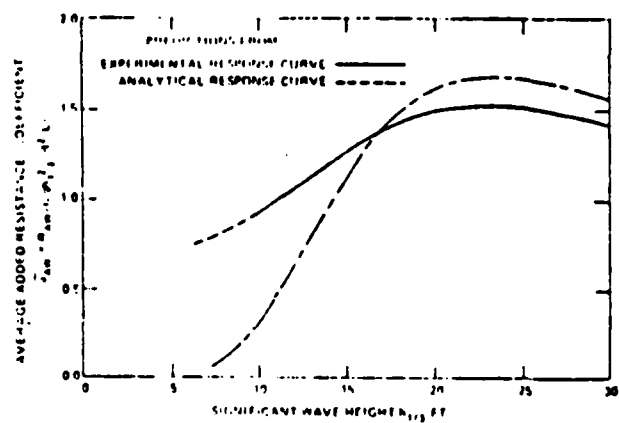
Analytical methods of calculating the added resistance of a ship in waves have shown reasonably good correlation with model tests. This study deals strictly with a ship encountering head seas since the calculation for added resistance in other seas becomes very complicated with the consideration of roll, yaw and sway motion. Only heave and pitch motions are considered. Fortunately added resistance is greatest for most ships in head seas (Ref. 21). The effect of the towline on added resistance is not considered.

A comparison of results of experimental and analytical predictions of added resistance can be seen in Figure 6-4. The spread of these curves is an indication of the degree of accuracy possible in calculating added resistance. This correspondence is partly dependent on the choice of the sea spectrum. The sea spectrum used in the development of these curves is the one parameter Pierson-Moskowitz. The curve for the regression analysis is derived from a sea spectrum recommended by the British Towing Tank Panel (BTTP) and is not of particular use in this study, since its use is restricted to ship forms which fall within the data base of the regression analysis.

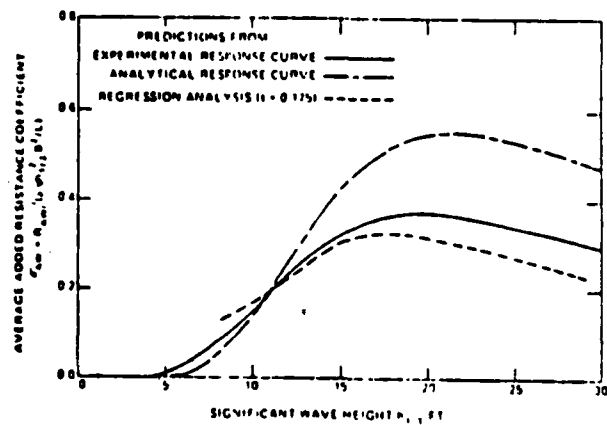
Reference 22 presents a tabular method for computing the added resistance of cruiser stern Series 60 ships. The method utilizes the Pierson-Moskowitz sea spectrum. It is possible using this method to obtain curves of added resistance for a particular cruiser stern ship as a function of ship speed and significant wave height. According to the authors, the added resistance calculated is generally low for short waves and high for long waves and for low speeds. The method is most accurate for Froude number ranging between 0.15 and 0.30 and for non-dimensional sea state of 0.02 and 0.04. The non-dimensional sea state is defined as significant wave height $H_{\frac{1}{3}}$ divided by ship length L . Figure 6-5 indicates that the results of the seakeeping tables for a Series 60 hull are close to those given by the analytical method. NSRDC has recently developed a method of computation for transom stern ships which was unavailable for this study.



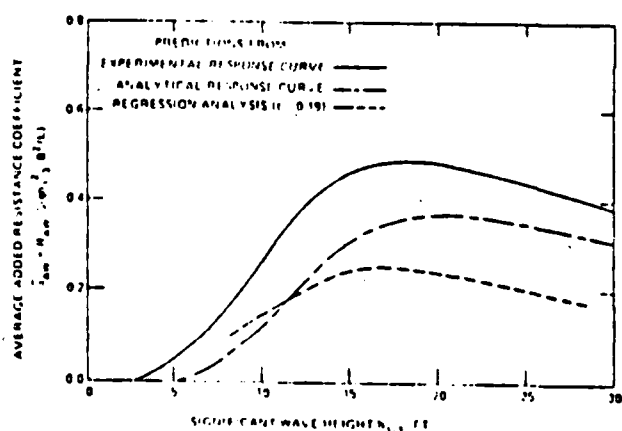
Destroyer hull form; $F_n = 0.35$



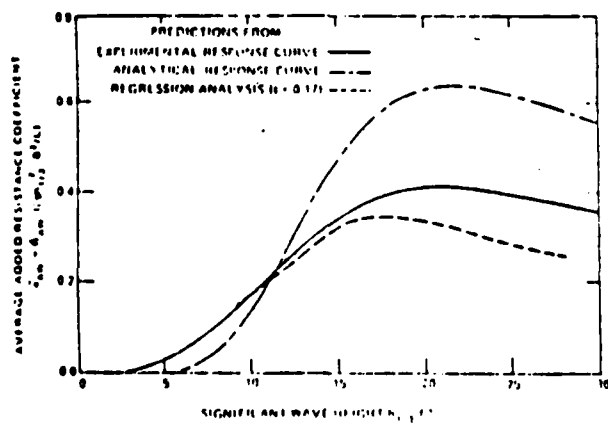
High-speed hull form; $F_n = 0.50$



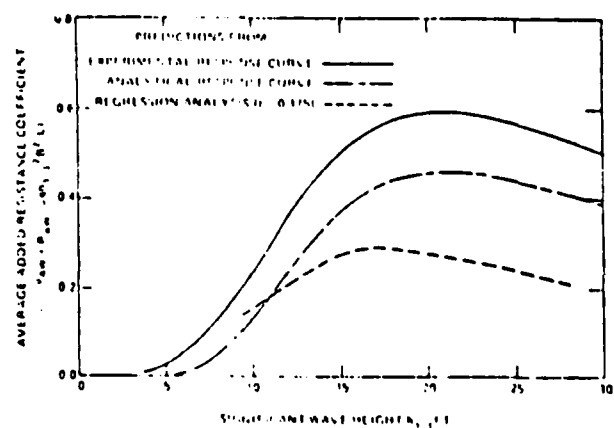
Series 60; $C_n = 0.70$, $F_n = 0.207$



Series 60; $C_n = 0.80$, $F_n = 0.147$



Series 60; $C_n = 0.65$, $F_n = 0.237$



Series 60; $C_n = 0.75$, $F_n = 0.177$

Figure 6-4

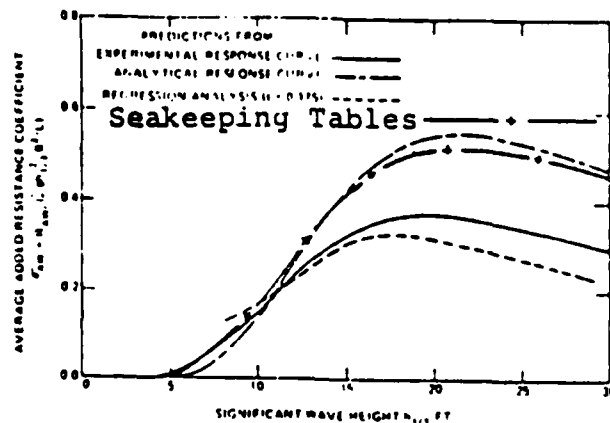


Fig6-5 Series 60, $C_b = 0.70$, $F_n = 0.207$ [Figure 20(c) of paper with discussor's seakeeping table predictions superimposed.]

Another difficult task in the analysis of added resistance is the selection of the proper sea spectrum to represent a seaway. The Pierson-Moskowitz spectrum is for fully developed seas but as indicated in Figure 6-6, a developing or decaying sea may have its spectral peak at a different frequency even at the same significant wave height.

As shown in Table 6-5 the average added resistance can change by as much as a factor of three with these changes in spectrum shape. Many investigators now feel a two parameter wave spectrum is necessary to describe a seaway and even this analysis may not properly account for short crested seas.

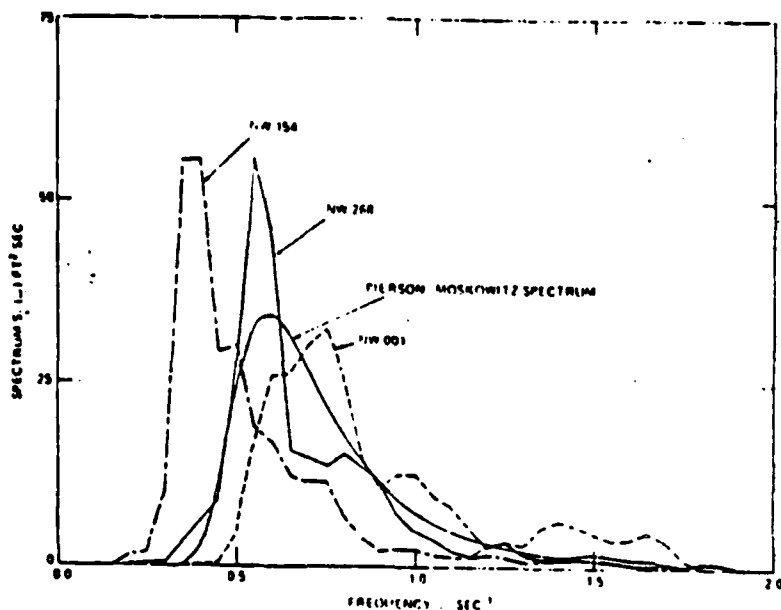


Fig. 6-6 Three typical North Atlantic sea spectra compared with Pierson-Moskowitz spectrum for same significant wave height (Ref. 21)

Ship Type	Ship Speed, Knots	Frontal Area, Sq. Ft.	Added Resistance, R_{WA} , lb. for Various Sea Spectra			
			NW 001	NW 154	NW 268	Pierson-Moskowitz
Destroyer	14.8	0.29	87,000	21,800	57,000	56,500
	21.0	0.27	95,000	25,700	74,000	65,000
	25.7	0.30	81,000	25,000	70,000	70,000
	29.4	0.30	63,000	20,000	56,000	74,000
High Speed Hull Form	16.8	0.23	53,500	21,000	42,750	67,400
	25.7	0.30	61,000	22,500	58,500	85,400
	31.6	0.40	44,000	24,000	60,000	89,000
	40.0	0.50	35,000	23,000	60,000	92,000
Series 60 $C_B = 0.60$	17.3	0.30	41,000	21,000	48,000	61,000
	27.4	0.30	28,000	20,000	40,000	50,000
Series 60 $C_B = 0.75$	17.3	0.27	31,000	21,000	40,000	51,000
	27.4	0.254	22,000	21,000	37,000	40,000
Series 60 $C_B = 0.70$	17.4	0.207	31,000	22,000	38,000	47,000
	19.7	0.202	31,000	20,000	38,000	46,000
Series 60 $C_B = 0.75$	14.9	0.177	34,000	22,000	38,000	47,000
	15.4	0.175	31,000	20,000	33,000	42,000
Series 60 $C_B = 0.80$	17.3	0.147	36,000	21,000	31,000	40,000
	11.9	0.105	30,000	20,000	31,000	37,000

Table 6-5. Added resistance for various 625-ft ship forms in Pierson-Moskowitz and three North Atlantic sea spectra (all at approximately the same significant wave height $h_{1/3} = 15$ ft) (Ref. 21)

A two parameter spectrum of the Bretschneider form which was recommended by the 12th ITTC (Rome 1969) is shown in Figure 6-7. This spectra has the parameters of significant wave height and wave period. Partially developed seas lie to the left of the Pierson-Moskowitz curve ($K=1$) for fully developed seas and dying seas and swell lie to the right of this line. Figure 6-8 shows the added resistance for one series 60 hull with the two parameters of significant wave height and wave period.

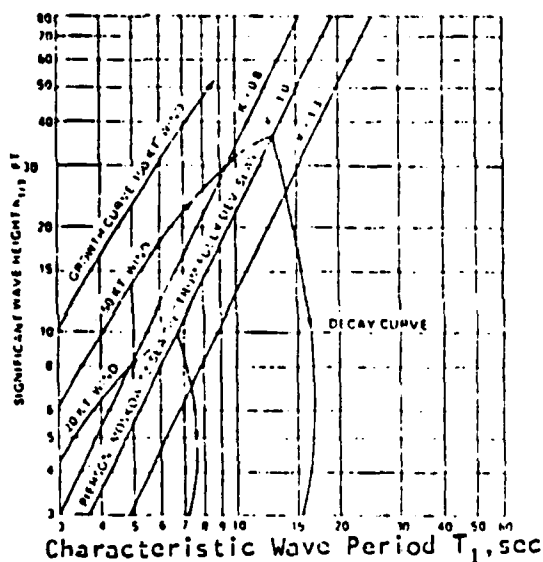


Fig.6-7.Characteristic Seas in the $T_1 - h^{1/3}$ Plane (Ref. 21)

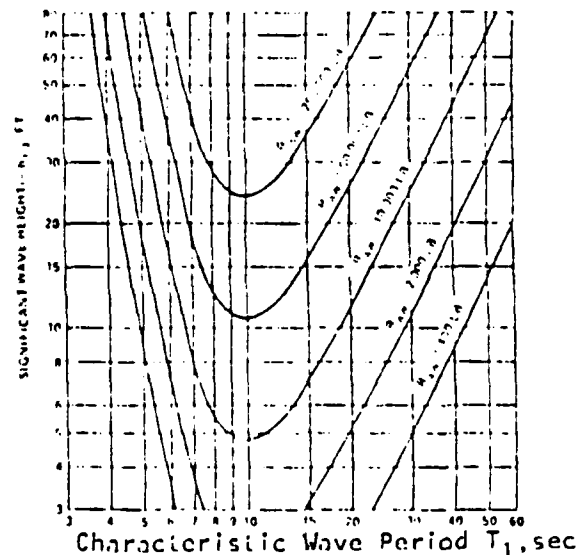


Fig.6-8. Typical Added Resistance Response Contours in the $T_1 - h^{1/3}$ Plane for 625-ft Ship (Series 60, $C_B = 0.70$) at 17.4 knots (Ref. 21)

By using Figures 6-7 and 6-8 together, it can be seen that for a 20 knot wind the characteristic wave period may vary from 5 to 7 seconds for a significant wave height of 8 feet. This results in an added resistance range of 400 to 10,000 pounds. (Ref.21).

Miles provides data for 323 wave spectra measured in the North Atlantic Ocean (Ref. 23). This data was used to calculate the added resistance for the one parameter, significant wave height, and is shown in Figure 6-9 (Ref. 21). The curve for the Pierson-Moskowitz spectra has been included. This demonstrates the error possible with the use of only one parameter and one spectrum.

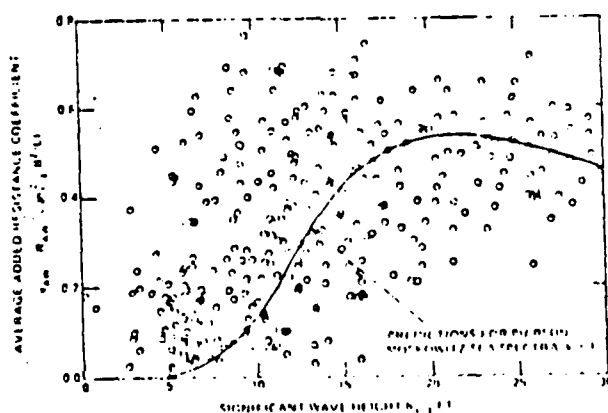


Fig. 6-9 Nondimensional added resistance versus significant wave height for 625-ft ship in 307 sample North Atlantic sea spectra (predictions from analytical response curve, Series 60, $C_B = 0.70$, $F_n = 0.207$) (Ref.21)

This study demonstrates that selection of the appropriate sea state may be equally important as the method of calculating the added resistance in obtaining accurate results.

6.2 Method of Calculation

To develop a simple method for determining the added resistance in waves, calculations were performed using the seakeeping tables for a Series 60 cruiser stern hull for nine ship classes. These classes were

selected to provide a wide range of ship lengths. Low Froude numbers of 0.1 to 0.15 were selected to provide a reasonable speed that could be employed while towing in a sea state. The added resistance in pounds (R_s) was plotted versus significant wave height and its corresponding wind force (Beaufort). The resulting curves for R_s are shown in figures 6-10 and 6-11. A curve from these two figures is assigned to each of the naval ship classes chiefly on the basis of ship length and to a lesser extent on the basis of block coefficient and length-beam ratio.

Since the lowest non-dimensional sea state used in the tables is 0.015 it was not possible to obtain added resistance data for Beaufort numbers below 5 for ships greater than 450 feet in length. Figure 6-11 shows that for the larger ships the added resistance converge together as they approach zero so one extrapolation line was used below a significant wave height of seven feet. In an effort to verify the accuracy of the extrapolated portion of figure 6-11 and the calculated points for low significant wave heights of figure 6-10 an empirical formula was used. As discussed in reference 27, several formulas exist for calculating added resistance for stationary or for moving ships but they give radically different results and do not account for all aspects of the added resistance problem. However, to compare with the results obtained by extrapolating the data from the seakeeping tables, the formula developed by Jacobs and Lewis was used to calculate added resistance for a significant wave height of 5 feet for the nine ships studied. Their equation is expressed:

$$R_s = 0.174 g \rho (h/2)^{1.67} (\sin \alpha)^{0.33} B^{1.33}$$

where R_s = added resistance (lb.)

h = wave height (ft.)

α = mean waterline entrance slope (deg.)

B = ship beam (feet)

This equation was developed for a stationary ship in short waves with the assumption that added resistance is due mainly to wave reflection and that added resistance due to pitching and heaving is negligible. This particular formulation was selected among others principally because Jacobs and Lewis obtained excellent agreement when they compared it with the results of model tests (Ref. 20).

The results of the calculations using the formulation above are presented in Appendix C. The mean waterline entrance slope was not known but was approximated on the basis of the ship characteristics. The results show close correlation with the seakeeping tables for the two smallest ships but differ by as much as a factor of 3 for larger ships. It is expected that the results of the seakeeping tables would be lower than that indicated by the Jacobs and Lewis formulation since these calculations were performed for tow speeds from six to nine knots. For low sea states, added resistance decreases as ship speed increases. Even if it is assumed that the formulation of Jacobs and Lewis is correct, the resulting error of 8000 pounds of added resistance amounts to less than 10 per cent of the tow resistance for the larger ships. On this basis the extrapolation for the lower significant wave heights is considered acceptable.

6.3 Accuracy of Results

The calculation of added resistance in wave is the least accurate of the four resistance components. The method of calculating added resistance in this study applies only to cruiser stern ships in head seas with a Pierson-Moskowitz sea spectrum. Only a one parameter wave spectrum was considered and it has been shown that small differences in wave period can produce substantial differences in added resistance due to waves. Until full scale testing in a sea state can be performed to verify the data presented by figures 6-10 and 6-11 especially for low sea states, this data should be used with caution. If for no other reason than added resistance in wave is now independent of calm water hull and propeller resistance, this approach can be considered an advance over the previous method as indicated by table 6-2.

K&S 10 X 10 TO 1/2 INCH 46 1322
7 X 10 INCHES
MADE IN U.S.A.
KEUFFEL & ESSER CO.

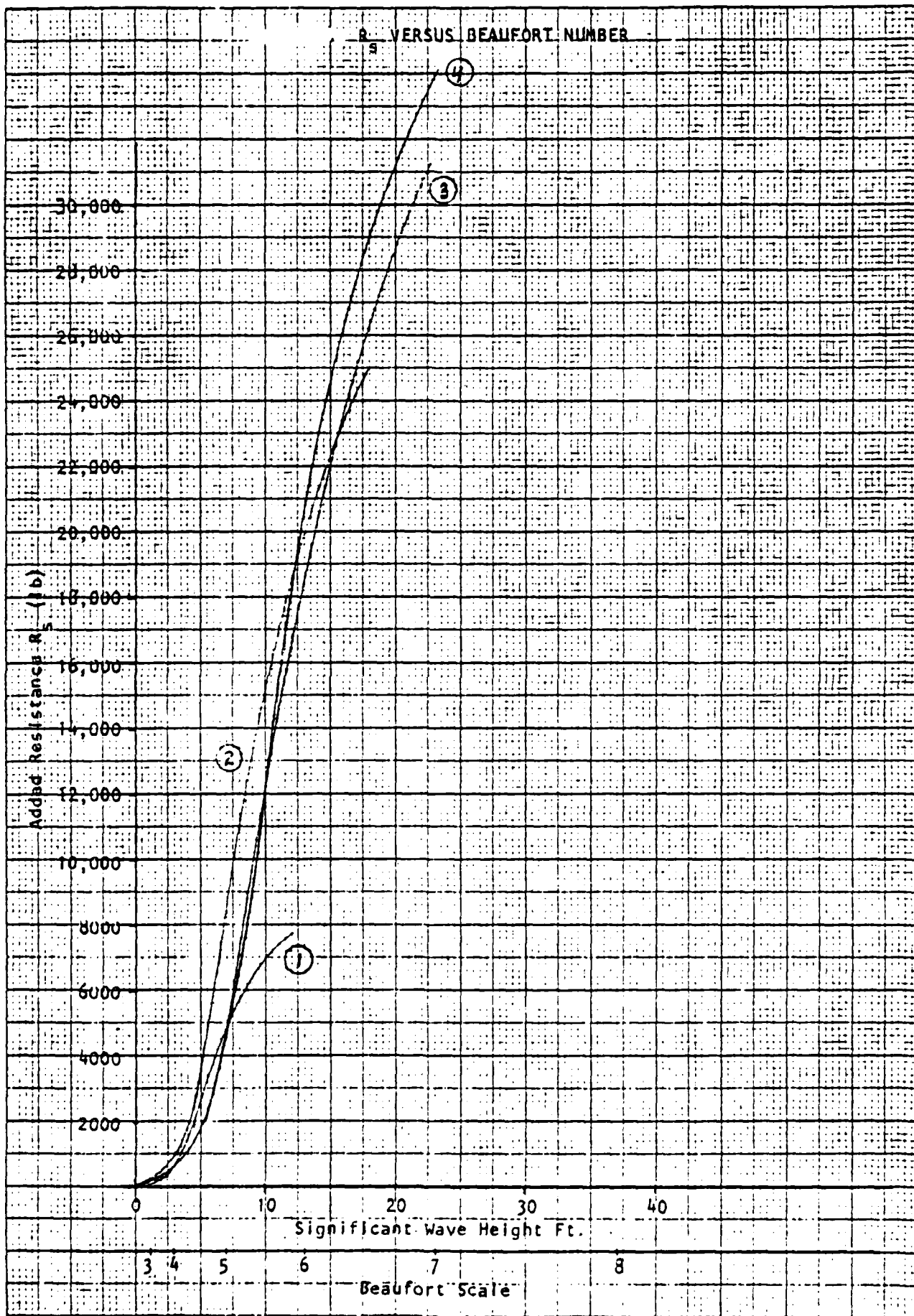


FIGURE 6-10

46 1322

K-E 10 X 10 TO 1 INCH 7 X 10 INCHES
KEUFEL & ESSER CO. MADE IN U.S.A.

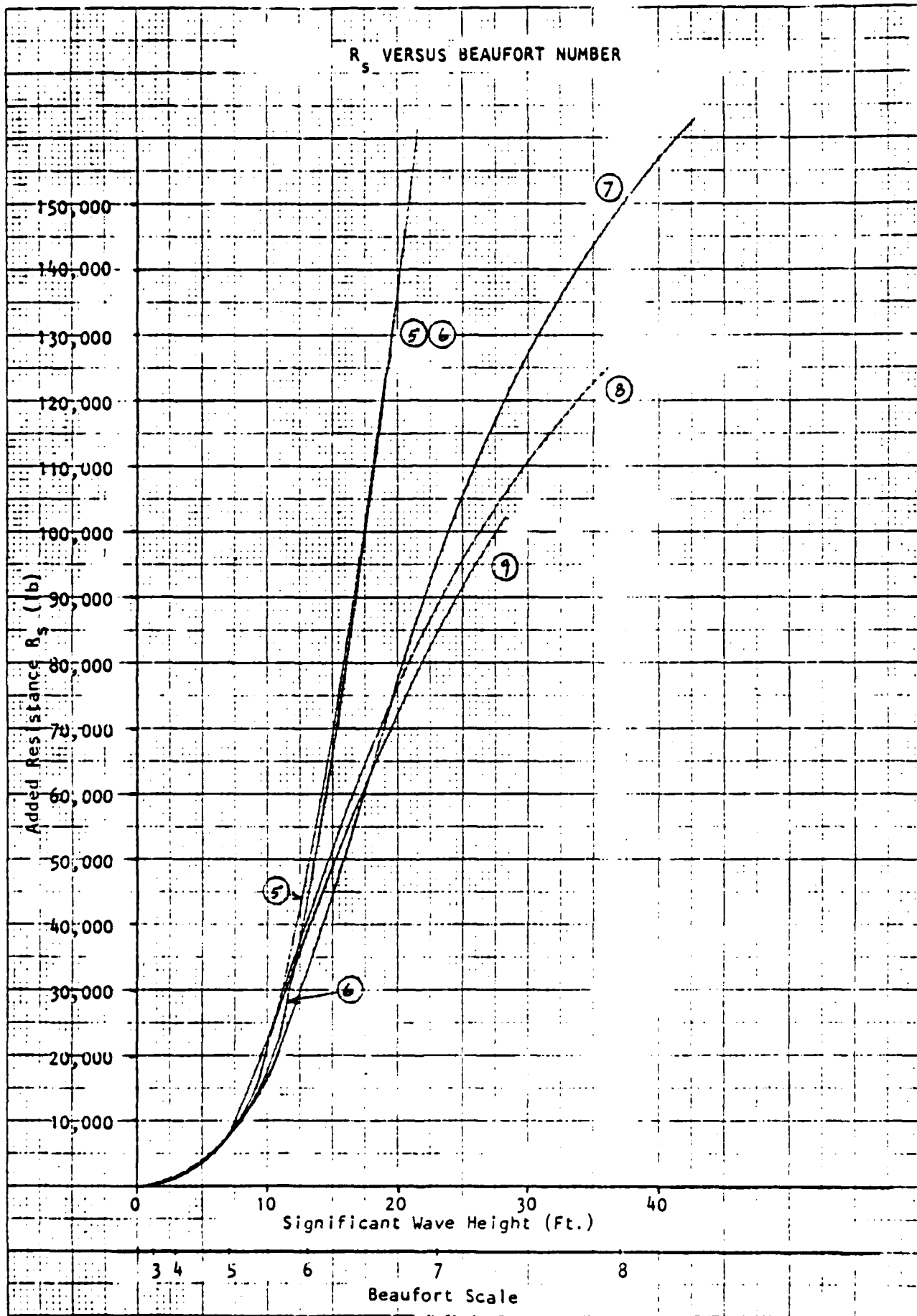


FIGURE 6-11

7. Calculation Procedure for the Determination of Tow Resistance

The previous sections have described the method of calculation for various components of the resistance: hull, propeller, wind and sea state. This section combines all of these components into one calculation for the determination of tow resistance. Resistance of the towline is not considered. The calculation of tow resistance is presented as a step by step procedure below. The items are summarized in tabular form in Table 1.

Item

1. Ship class
- 2-8 Data for given ship class taken from Table 2
2. Displacement Δ in long tons
3. Frontal windage area A_T in Feet²
4. Wind drag coefficient C_w
5. Projected area of all propellers A_p in Feet²
6. Curve number for hull resistance
7. Curve number for K factor
8. Curve number for sea state resistance R_s
9. Determine wind Beaufort number based on measurement of wind velocity and observation of the sea state with the aid of Table 3. The estimate should be conservative and should account for anticipated changes of weather.
10. Relative wind speed V_R in knots
11. Relative wind direction α measured in degrees measured from the bow
12. Using the appropriate curve from item 7 find the heading coefficient K for the heading angle α from item 11. See Figures 1-3.

Item

13. Using the appropriate curve from item 8 determine the sea state resistance R_s for the appropriate Beaufort number from item 9. See Figures 4 and 5.
14. Select tow speed V_{TOW} in knots
15. Using curve number from item 6 and Figures (6) through (13), find the value for R_H/Δ for the tow speed selected, item 14.
16. Calculate the hull resistance R_H .

$$R_H = R_H/\Delta \times \Delta \times 1.25$$

17. Calculate the propeller resistance R_p .

$$R_p = 3.737 A_p V_{tow}^2$$

18. Calculate the wind resistance R_w

$$R_w = 0.00506 C_w A_t K V_R^2$$

19. Calculate the total resistance R_T .

$$R_T = R_s + R_H + R_p + R_w$$

Special Note: If the tow does not track directly behind the towing vessel or if it is towing at an angle of yaw then the ship speed should be reduced below the maximum speed permitted by the above calculation. Speed should always be reduced below this maximum value while turning.

TABLE - I
CALCULATION OF TOWING RESISTANCE

SHIP: _____		DATE: _____	
		BY: _____	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		
2	TOW DISPLACEMENT, Δ (SEE TABLE-2)	LONG TONS	
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 2)	SQ. FEET	
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 2)	—	
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 2)	SQ. FEET	
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 2)	—	
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 2)	—	
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 2)	—	
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-3)	—	
10	RELATIVE WIND SPEED, V_R	KNOTS	
11	RELATIVE WIND DIRECTION, α	DEGREES	
12	HEADING COEFFICIENT K , (SEE FIG. 1-3)	—	
13	SEA STATE RESISTANCE R_s , (SEE FIG. 4-5)	POUNDS	
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	
15	R_H/Δ (SEE FIG. 6-13)	—	
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-13)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
AD 14-19	Destroyer Tender	17176	6200	0.75	136	14	1	9
AD 16	"	16600	4130	0.75	142	26	1	8
AD 23-36	"	16900	4200	0.75	142	26	1	8
AD 37-38	"	21000	5600	0.75	136	21	1	5
ADG 8-10	Degaussing Ship	900	1100	0.75	24	13	1	1
ADG 383	"	1235	--	0.75	--	30	1	2
AE 4-9	Ammunition Ship	14225	4600	0.75	103	26	1	8
AE 12-19	"	15295	4500	0.75	103	26	1	8
AE 21-25	"	17500	6490	0.75	187	13	1	8
AE 26-35	"	20500	--	0.75	--	15	1	9
AE 30-31	"	14000	4375	0.75	106	26	1	3
AF 28-29	Stores Ship	15300	4460	0.75	106	26	1	2
AF 42-44	"	7435	2600	0.75	38	26	1	8
AF 48-61	"	15500	4405	0.75	106	26	1	8
T-AF 50-51	"	12800	4375	0.75	106	26	1	8
AF 56-57	"	12130	4100	0.75	119	26	1	8
AF 58-59	"	15540	5400	0.75	198	12	1	8
T-AF 63-64	"	12130	4100	0.75	119	26	1	8
AFS 1-7	Combat Stores Ship	16500	6350	0.70	216	17	3	3
AG 153-154	Exper. Navigation Ship	17600	5550	0.75	--	17	1	8
T-AG 162	Exper. Sound Testing	17000	--	0.75	--	--	1	--
T-AG 164	Hydrographic Research	12450	4340	0.75	119	13	1	8
T-AG 169-171	Special Mission	7460	2600	0.75	38	26	1	4

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-12)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
AD 14-19	Destroyer Tender	17176	6200	0.75	136	14	1	9
AD 16	"	16600	4130	0.75	142	26	1	8
AD 23-36	"	16900	4200	0.75	142	26	1	8
AD 37-38	"	21000	5600	0.75	136	21	1	5
ADG 8-10	Degaussing Ship	900	1100	0.75	24	13	1	1
ADG 383	"	1235	--	0.75	--	30	1	2
AE 4-9	Ammunition Ship	14225	4600	0.75	103	26	1	8
AE 12-19	"	15295	4500	0.75	103	26	1	8
AE 21-25	"	17500	6490	0.75	187	13	1	8
AE 26-35	"	20500	--	0.75	--	15	1	9
AE 30-31	"	14000	4375	0.75	106	26	1	3
AF 28-29	Stores Ship	15300	4460	0.75	106	26	1	2
AF 42-44	"	7435	2600	0.75	38	26	1	8
AF 48-61	"	15500	4405	0.75	106	26	1	8
T-AF 50-51	"	12800	4375	0.75	106	26	1	8
AF 56-57	"	12130	4100	0.75	119	26	1	8
AF 58-59	"	15540	5400	0.75	198	12	1	8
T-AF 63-64	"	12130	4100	0.75	119	26	1	8
AFS 1-7	Combat Stores Ship	16500	6350	0.70	216	17	3	3
AG 153-154	Exper. Navigation Ship	17600	5550	0.75	--	17	1	8
T-AG 162	Exper. Sound Testing	17000	--	0.75	--	--	1	--
T-AG 164	Hydrographic Research	12450	4340	0.75	119	13	1	8
T-AG 169-171	Special Mission	7460	2600	0.75	38	26	1	4

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-12)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
T-AG 172-174	Cargo	12400	4100	0.75	119	13	1	8
T-AG 175	Surveying Ship	7400	2600	0.75	38	26	1	4
AG 176	Miscellaneous	--	--	0.75	--	--	1	2
T-AG 178	Hydrographic Research	11000	4375	0.75	106	37	1	8
AG 191	Sonar Test Ship	8200	2600	0.75	--	2	1	3
AG 335	Cargo	1095	990	0.75	22	29	1	1
AGDE 1	Escort Research	3426	1715	0.75	131	10	1	4
AGF 1	Misc. Command Ship	2800	1600	0.75	47	16	1	2
T-AGM 1-11	Missile Range Inst. Ship	11100	4100	0.70	119	20	3	8
T-AGM 2	"	550	--	0.70	--	--	--	--
T-AGM 9-10	"	16600	4900	0.70	--	17	3	5
T-AGM 13-16	"	7460	2600	0.70	38	26	3	4
T-AGM 19-21	"	21626	5020	0.70	--	37	3	9
AGMR 1	Communications Relay	22500	--	0.75	--	15	1	9
AGMR 2	"	19600	6000	0.75	300	3	1	7
T-AGS 29-32	Surveying Ship	4200	--	0.75	--	11	1	4
AGTR 1-3	Technical Research	11365	3250	0.75	94	26	1	8
AGTR 4-5	"	10680	4100	0.75	119	13	1	8
AH 16-17	Hospital Ship	15900	4900	0.75	115	17	1	8
T-AK 180-250	Cargo Ship	7450	3100	0.75	38	26	1	4
T-AK 237-276	"	12450	4100	0.75	119	13	1	8
T-AK 241-254	"	12400	4100	0.75	119	13	1	8
T-AK 255-267	"	--	4900	0.75	--	17	1	5

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-1)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
AK 260	CARGO SHIP	12420	4100	0.75	119	13	1	8
T-AK 271	"	4942	--	0.75	--	26	1	2
T-AK 277	"	15800	5400	0.75	142	13	1	8
T-AK 279-281	"	11150	4100	0.75	119	20	1	8
T-AK 283	"	14000	4375	0.75	106	26	1	8
T-AKD 1	Dock Cargo Ship	14094	6856	0.75	--	26	1	8
T-AKR 7	Vehicle Cargo Ship	18150	--	0.75	--	13	1	8
T-AKR 9	"	21700	--	0.75	--	20	1	9
T-AKV 8-37	Cargo/Aircraft Ferry	24560	5400	0.75	158	20	1	9
T-AKV 40-43	"	15700	5340	0.75	--	13	1	8
AO 24-53	Oiler	25400-34700	5540	1.00	174	20	2	5
AO 36-47	"	21850	4290	1.00	108	26	2	9
T-AO 49-142	"	22380	4610	1.00	108	26	2	9
AO 105-109	"	34750	5480	1.00	346	26	2	5
AO 143-148	"	38000	6300	1.00	198	26	2	5
T-AO 149-152	"	--	--	1.00	--	--	2	--
T-AO 165	"	--	--	1.00	--	--	2	--
AOE 1-5	Fast Combat Support	53600	9750	0.75	456	22	1	6
AOG 1-56	Gasoline Tanker	4570	2200	1.00	54	26	2	2
T-AOG 77-80	"	6000	--	1.00	--	26	2	4
T-AOG 81-82	"	5720	--	1.00	--	--	2	--
AOR 1-6	Replenishment Oiler	38100	7590	1.00	274	20	2	5
T-AP 110-119	Transport	20175	6800	0.75	200	23	1	9

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	WINDAGE (SQ. FT.)	FRONTAL AREA (SQ. FT.)	WIND COEFF. C _w	TOTAL PROJECTED AREA OF ALL PROPELLERS A _p (FEET) ²	R _L See 1
T-AP 122-127	Transport	20620	--	0.75	--	--	--
T-AP 196-198	"	19600	--	0.75	--	--	--
APB 35-48	Self Propelled Barracks	4080	7460	0.75	30	13	26
APC 116	Coastal Transport	2660	16130	0.75	38	26	26
AR 2-58	Barracks Barges	14500	14490	0.75	--	--	--
AR 5-8	Repair Ship	16900	4080	0.75	136	14	20
AR 9-12	"	7380	7080	0.75	142	15	26
AR 13-14	"	14350	3830	0.75	142	14	20
AR 22-23	"	1900	1095	0.75	30	15	26
ARB 4-8	"	4080	4080	0.75	37	26	37
ARC 2-6	"	4080	4080	0.75	26	37	26
ARC 3-4	"	13475	14500	0.75	19	--	--
ARG-4	"	18000	18000	0.75	--	--	--
ARL 1-38	Battle Damage Repair	5460	16130	0.75	--	--	--
ARS 6-43	Cable Repair Ship	4100	14500	0.75	--	--	--
ARSD 1-2	"	4200	14490	0.75	--	--	--
ARST 1-2	Engine Repair Ship	4180	16900	0.75	--	--	--
ARVA 5-6	Landing Craft Repair	2320	4080	0.75	--	--	--
ARVE 4	Salvage Ship	--	7380	0.75	--	--	--
T-ARV H1	Salvage Lift Ship	--	7080	0.75	--	--	--
AS 13-14	Salvage Craft Repair	3250	14350	0.75	--	--	--
AS 11-18	Aircraft Craft Tender	2320	3830	0.75	--	--	--
AS 19	Aircraft Airframe Rpr.	1500	1900	0.75	--	--	--
"	Helicopter Repair Rpr.	990	1095	0.75	--	--	--
"	Submarine Tender	2320	4080	0.75	--	--	--
"	"	2320	4080	0.75	--	--	--
"	"	510	13475	0.75	--	--	--
"	"	510	14500	0.75	--	--	--
"	"	510	18000	0.75	--	--	--

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-12)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
AS 22	Submarine Tender	15400	4300	0.75	142	26	1	8
AS 23	"	16100	4300	0.75	142	26	1	8
AS 31-32	"	18300	6440	0.75	140	12	1	8
AS 33-34	"	22250	7550	0.75	136	23	1	5
AS 36-37	"	22640	7550	0.75	136	23	1	5
ASR 7-16	"	2290	1200	0.75	50	21	1	2
ASR 12-20	"	1760	1170	0.75	50	8	1	1
ASR 21-22	"	3411	--	0.75	--	--	1	--
ATF 67-162	Fleet Ocean Tug	1675	1200	0.75	43	9	1	2
AV 7-13	Sea Plane Tender	15090	5100	0.75	136	17	1	9
AV 10	"	14200	4500	0.75	142	20	1	8
AVB 2	Advanced Aviation Base	6000	3940	0.75	54	37	1	4
AVM 1	Guided Missile Ship	15170	5300	0.75	136	37	1	3
AVT 9	Electronics Test Ship	38500	8300	0.75	--	10	1	6
AW 4	Distilling Ship	22380	4600	0.75	108	26	1	9
BB 61-64	Battleship	59000	8500	0.70	664	14	3	6
CA 68-130	Heavy Cruiser	17500	5300	0.70	308	7	3	7
CA 122-124	Heavy Cruiser	17500	5300	0.70	308	7	3	7
CA 134-148	"	21470	4500	0.70	324	7	3	7
CC 1	Command Ship	17200	5300	0.70	308	7	3	7
CC 2	"	19600	6000	0.70	300	10	3	7
CG 10-12	Guided Missile Cruiser	17700	6300	0.70	308	6	3	7
CGN 9	"	17350	7900	0.70	312	6	3	7

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-1)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
CL 65-103	Light Cruiser	13755	4300	0.70	256	4	3	5
CL 106	"	14055	4300	0.70	256	4	3	5
CL 144-145	"	18700	5000	0.70	324	7	3	7
CLG 3-8	Guided Missile Lt. Cruiser	14600	4000	0.70	256	7	3	5
CVA 14-34	Attack Aircraft Carrier	42600	8300	0.45	300	27	3	6
CVA 41-43	"	62000	--	0.45	--	27	3	6
CVA 59-62	"	78040	13100	0.45	1028	28	3	6
CVA 63	"	75200	13100	0.45	1028	28	3	6
CVA 64	"	75200	13100	0.45	1028	28	3	6
CVA 66	"	78250	13100	0.45	1028	28	3	6
CVA 67	"	83000	13100	0.45	1028	28	3	6
CVAN	"	85350	16600	0.45	--	27	3	6
CVAN 68-70	"	95100	--	0.45	--	27	3	6
CVS 9-39	ASW Aircraft Carrier	41000	8300	0.45	300	27	3	6
CVT 16	Training Carrier	41000	8300	0.45	300	27	3	6
DD 422-617	Destroyer	2575	1400	0.70	74	3	3	2
DD 423-647	"	2590	1400	0.70	74	3	3	2
DD 445-795	"	3040	1400	0.70	134	35	3	4
DD 692-857	"	3400	1400	0.70	158	35	3	4
DD 710-890	"	3540	1450	0.70	158	35	3	4
DD 712	"	3480	1450	0.70	158	35	3	4
DD 719-824	"	3500	1450	0.70	158	35	3	4

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-13)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
DD 825-827	Destroyer	3410	1450	0.70	158	35	3	4
DD 931-951	"	4200	2100	0.70	194	3	3	4
DD 963-967	"	7000	--	0.70	254	32	3	4
DDG 2-24	Guided Missile Destroyer	4500	2256	0.70	176	31	3	8
DDG 31-34	"	4200	2100	0.70	194	35	3	4
DDG 35-36	"	4730	2800	0.70	222	30	3	8
DE 129-399	Escort Ship	1990	1400	0.70	52	35	3	4
DE 162-767	"	2230	1200	0.70	52	35	3	4
DE 202-800	"	2230	1200	0.70	52	35	3	4
DE 224-708	"	2230	1200	0.70	52	35	3	4
DE 339-538	"	2100	1200	0.70	52	1	3	4
DE 1006-1037	"	1914	1342	0.70	79	1	3	4
DE 1033-1036	"	1750	1340	0.70	--	1	3	4
DE 1037-1038	"	2650	--	0.70	--	1	3	4
DE 1040-1051	"	3400	1715	0.70	131	2	3	4
DE 1052-1097	"	4100	2020	0.70	131	30	3	4
DEG 1-6	Guided Missile Escorts	3600	1715	0.70	131	2	3	4
DER 147-400	Radar Picket Escorts	1850	1400	0.70	52	1	3	2
DER 539-540	"	2100	1400	0.70	52	1	3	2
DL1	Frigate	7300	2600	0.70	--	36	3	3
DL 4-5	"	4730	2800	0.70	222	30	3	3
DLG 6-15	Guided Missile Frigate	5800	--	0.70	--	32	3	3
DLG 16-24	"	7800	--	0.70	--	4	3	3

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS (FEET) ² A_p	CURVE FOR HULL RESISTANCE See Fig. (6-12)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
DLG 26-34	Guided Missile Frigate	7930	3675	0.70	296	34	3	3
DLGN 25	"	8580	3040	0.70	--	5	3	3
DLGN 35	"	9200	2960	0.70	--	5	3	3
DLGN 36-37	"	10150	--	--	--	--	--	--
DLGN 38-41	"	10000	--	--	--	--	--	--
IX 21	Sail Frigate	2200	--	--	--	--	--	--
IX 304	Experimental Target	13755	4300	0.70	--	7	3	5
LCC 7-17	Amphibious Command	12560	4300	0.70	97	26	3	8
LCC 19-20	"	17100	--	0.70	--	38	3	3
LHA 1-3	Amphibious Assault Ship	40000	8800	0.70	262	25	3	6
LKA 19-97	Amphibious Cargo Ship	14000	4300	0.75	113	26	1	8
LKA 103-108	"	14160	4300	0.75	113	26	1	8
LKA 112	"	15970	4900	0.75	--	12	1	9
LKA 113	"	20700	--	0.75	--	--	--	--
LPA 33-44	Amphibious Transport	15200	5400	0.75	143	13	1	8
LPA 194-237	"	10470	4100	0.75	119	13	1	8
LPA 248-249	"	16840	4900	0.75	--	14	1	9
LPD 1-3	Amphibious Dock	13500	6050	0.75	--	12	1	9
LPD 4-15	"	16900	6050	0.75	--	16	1	9
LPH 2-12	Amphibious Assault Ship	18300	--	0.75	--	39	1	9
LPH 4-8	"	40600	8300	0.75	300	28	1	6
LPR 55-135	Amphibious Trans. Small	2130	1400	0.75	52	1	1	2
LPSS 315	Amphibious Trans. Sub.	2045	450	0.75	--	30	1	2

TABLE 2 - CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT Δ (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	WIND COEFF. C_w	TOTAL PROJECTED AREA OF ALL PROPELLERS A_p (FEET) ²	CURVE FOR HULL RESISTANCE See Fig. (6-13)	CURVE FOR K FACTOR See Fig. (1-3)	CURVE FOR SEA STATE R_s See Fig. (4-5)
LPSS 574	Amphibious Trans. Sub.	2670	--	0.75	--	--	1	--
LSD 1-7	Dock Landing Ship	8700	4100	0.75	64	19	1	8
LSD 13-27	"	9375	--	0.75	64	19	1	8
LSD 28-35	"	11270	5695	0.75	174	19	1	9
LSD 36-40	"	13650	5700	0.75	--	19	1	6
T-LST 47-1088	Tank Landing Ship	4080	2000	0.75	30	37	1	2
LST 334-509	"	4080	2000	0.75	30	37	1	2
LST 515-1150	"	4080	2000	0.75	30	37	1	2
LST 1153	"	6000	3940	0.75	54	37	1	4
LST 1156-1170	"	5800	3940	0.75	54	37	1	4
LST 1171-1178	"	8000	3400	0.75	82	37	1	8
LST 1179-1198	"	8342	--	0.75	108.14	18	1	9
MCS 1-2	Mine Counter Measures	9040	4230	0.75	76	16	1	8
MHC 43	Coastal Mine Hunter	--	--	0.75	--	--	1	1
MMD 23-33	Fast Minelayers	3320	1400	0.75	158	35	1	4
MMF 5	Fleet Minelayer	8680	--	0.75	76	11	1	8
MSO 421-496	Ocean Minesweeper	750	--	0.75	40.28	8	1	1

TABLE 3 - BEAUFORT SCALE

SEA STATE	SEA DESCRIPTION	WIND							WAVE HEIGHT (FEET)
		WIND FORCE (BEAUFORT)	DESCRIPTION	RANGE (KNOTS)	WIND VELOCITY (KNOTS)	AVERAGE	SIGNIFICANT	AVERAGE TO HIGHEST	
0	SEA LIKE A MIRROR	0	CALM	<1	0**	0	0	0	0
	RIPPLES WITH THE APPEARANCE OF SCALES ARE FORMED, BUT WITHOUT FOAM CRESTS	1	LIGHT AIR	1-3	2	0.03	0.08	0.10	
1	SMALL WAVELETS, STILL SHORT BUT MORE PRONOUNCED. CRESTS HAVE A GLASSY APPEARANCE BUT DO NOT BREAK	2	LIGHT BREEZE	4-6	3	0.16	0.29	0.37	
	LARGE WAVELETS, CRESTS BEGIN TO BREAK. FOAM OF GLASSY APPEARANCE. PERHAPS SCATTERED WHITE HORSES	3	GENTLE BREEZE	7-10	8.5 10	0.6 0.88	1.0 1.4	1.2 1.8	
2	SMALL WAVES, BECOMING LARGER, FAIRLY FREQUENT WHITE HORSES	4	MODERATE BREEZE	11-16	12	1.4	2.2	2.8	
					13.5 14	1.8 2.0	2.9 3.3	3.7 4.2	
3	MODERATE WAVES, TAKING A MORE PRONOUNCED LONG FORM. MANY WHITE HORSES ARE FORMED (CHANCE OF SOME SPRAY)	5	FRESH BREEZE	17-21	16	2.8	4.1	7.6	
					19 20	4.3 5.0	6.9 8.0	8.7 10	
4	LARGE WAVES BEGIN TO FORM. THE WHITE FOAM CRESTS ARE MORE EXTENSIVE EVERYWHERE (PROBABLY SOME SPRAY)	6	STRONG BREEZE	22-27	22	6.4	10	13	
					24 24.5 26	7.9 8.2 9.6	12 13 15	16 17 20	
5	SEA HEAPS UP AND WHITE FOAM FROM BREAKING WAVES BEGINS TO BE BLOWN IN STREAKS ALONG THE DIRECTION OF THE WIND (SPINDRIFT BEGINS TO BE SEEN)	7	MODERATE GALE	28-33	28	11	18	23	
					30 30.5 32	14 14 16	22 23 26	28 29 33	
6	MODERATELY HIGH WAVES OF GREATER LENGTH. EDGES OF CRESTS BREAK INTO SPINDRIFT. THE FOAM IS BLOWN IN WELL MARKED STREAKS ALONG THE DIRECTION OF THE WIND. SPRAY AFFECTS VISIBILITY	8	FRESH GALE	34-40	34	19	30	38	
					36 37 38 40	21 23 25 28	33 37 40 45	46 48.7 50 58	
7	HIGH WAVES. DENSE STREAKS OF FOAM ALONG THE DIRECTION OF THE WIND. SEA BEGINS TO ROLL. VISIBILITY AFFECTED	9	STRONG GALE	41-47	42	31	50	64	
					44 46	36 40	58 64	73 81	
8	VERY HIGH WAVES WITH LONG OVERHANGING CRESTS. THE RESULTING FOAM IS IN GREAT PATCHES AND IS BLOWN IN DENSE WHITE STREAKS ALONG THE DIRECTION OF THE WIND. ON THE WHOLE THE SURFACE OF THE SEA TAKES A WHITE APPEARANCE. THE ROLLING OF THE SEA BECOMES HEAVY AND SHOCKING. VISIBILITY IS AFFECTED	10	WHOLE GALE*	48-55	48	46	71	90	
					50 51.5 52 54	49 52 54 59	76 83 87 95	99 106 110 121	
9	EXCEPTIONALLY HIGH WAVES (SMALL AND MEDIUM SIZED SHIPS MIGHT FOR A LONG TIME BE LOST TO VIEW BEHIND THE WAVES). THE SEA IS COMPLETELY COVERED WITH LONG WHITE PATCHES OF FOAM LYING ALONG THE DIRECTION OF THE WIND. EVERYWHERE THE EDGES OF THE WAVE CRESTS ARE BLOWN INTO FROTH. VISIBILITY AFFECTED	11	STORM*	56-63	56	64	102	130	
					59.5	73	116	148	
10	AIR FILLED WITH FOAM AND SPRAY. SEA COMPLETELY WHITE WITH DRIVING SPRAY. VISIBILITY VERY SERIOUSLY AFFECTED	12	HURRICANE*	64-71	>64	>80**	>128**	>164**	

* FOR HURRICANE WINDS (AND OFTEN WHOLE GALE AND STORM WINDS) REQUIRED DURATIONS AND FETCHES ARE RARELY ATTAINED. SEAS ARE THEREFORE NOT FULLY RISEN.

** A HEAVY BOX AROUND THIS VALUE MEANS THAT THE VALUES TABULATED ARE AT THE CENTER OF THE BEAUFORT RANGE.

FIGURE 1 - CURVE 1

CARGO SHIPS

WIND "K" CURVE

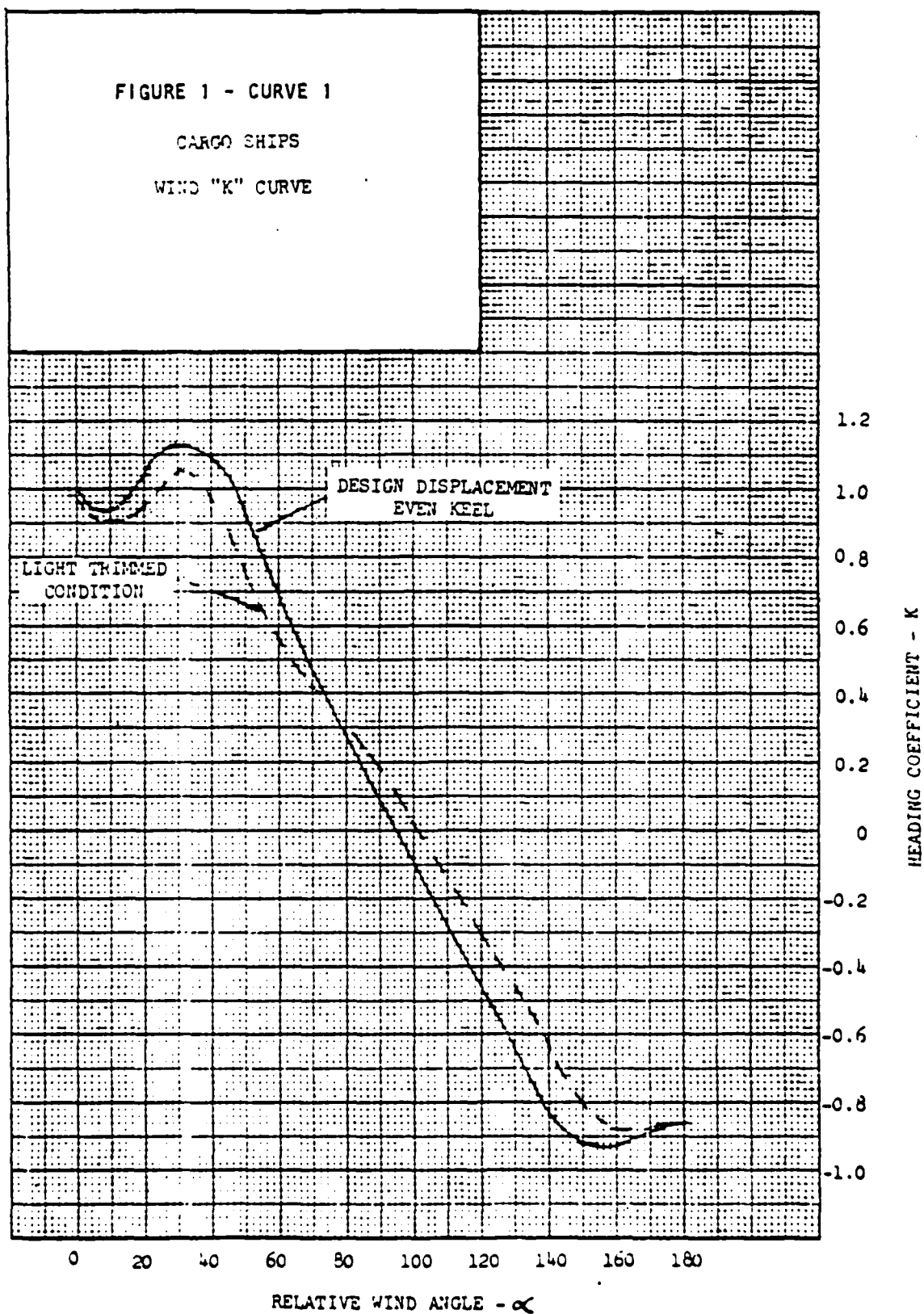


FIGURE 2 - CURVE 2

TANKERS

WIND "K" CURVES

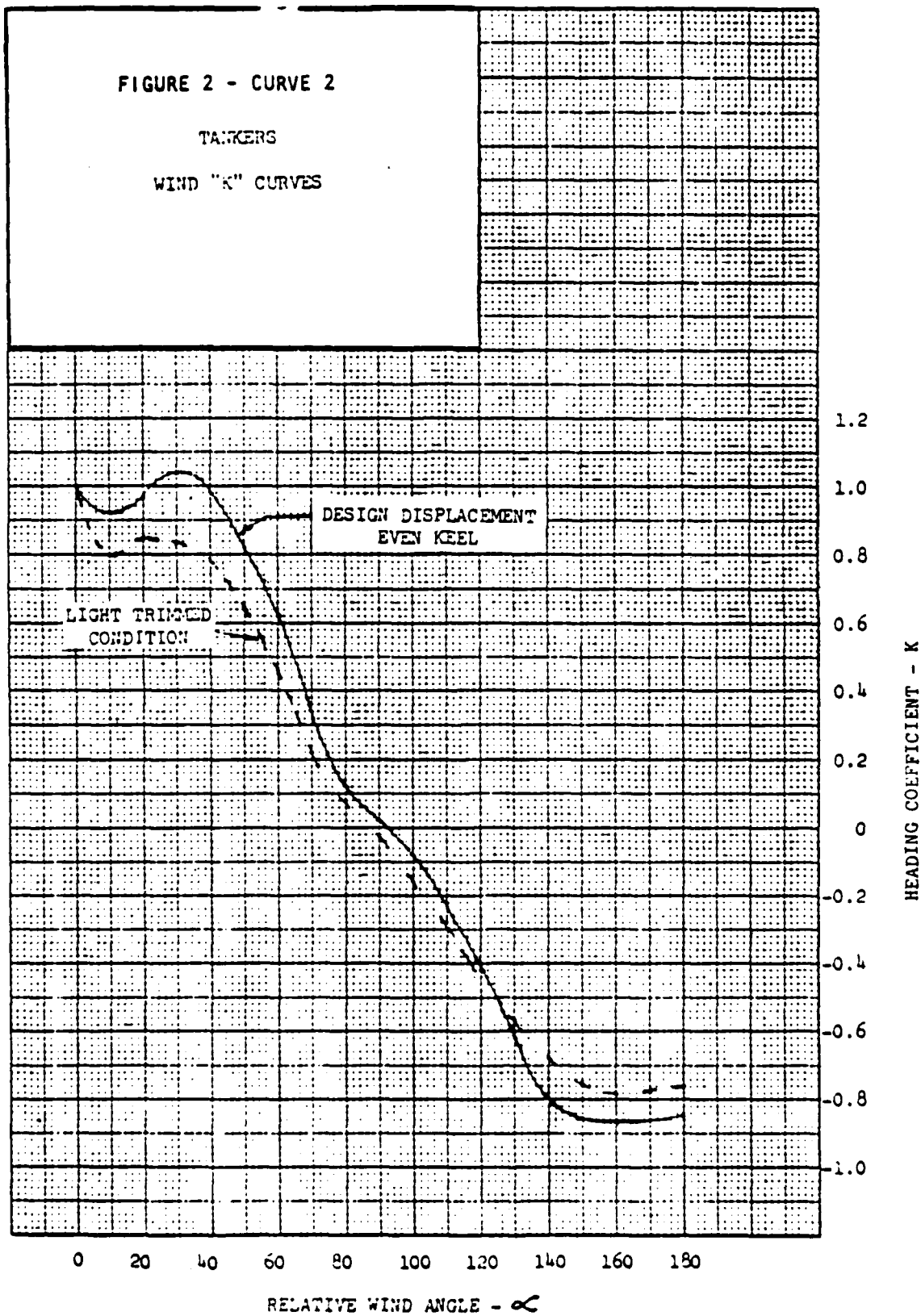
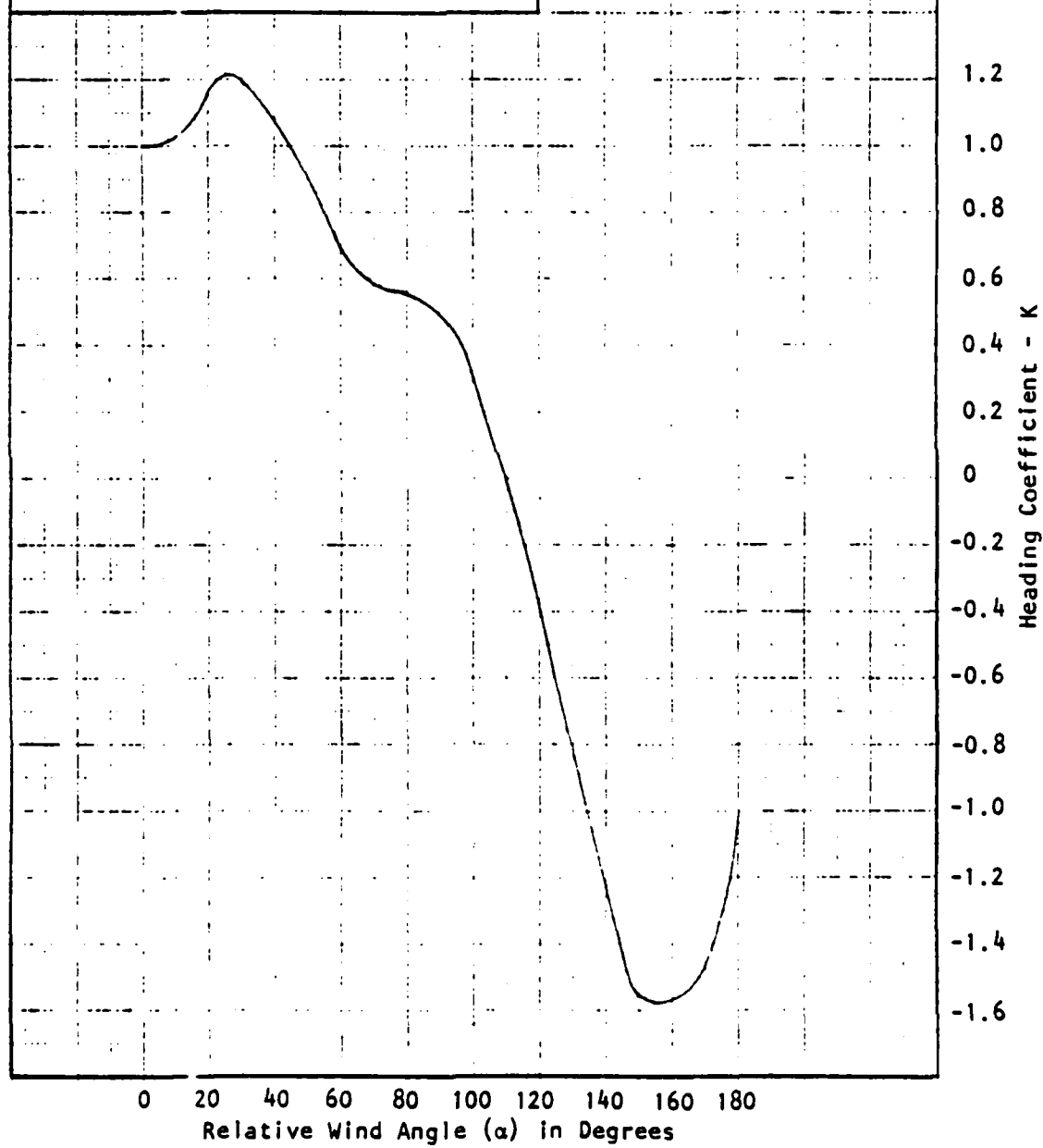


Figure 3 - Curve 3

Naval Combatants

Wind "K" Curve



K&E 10 X 10 TO 1/2 INCH 46 1322
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

FIGURE 4. R_s VERSUS BEAUFORT NUMBER

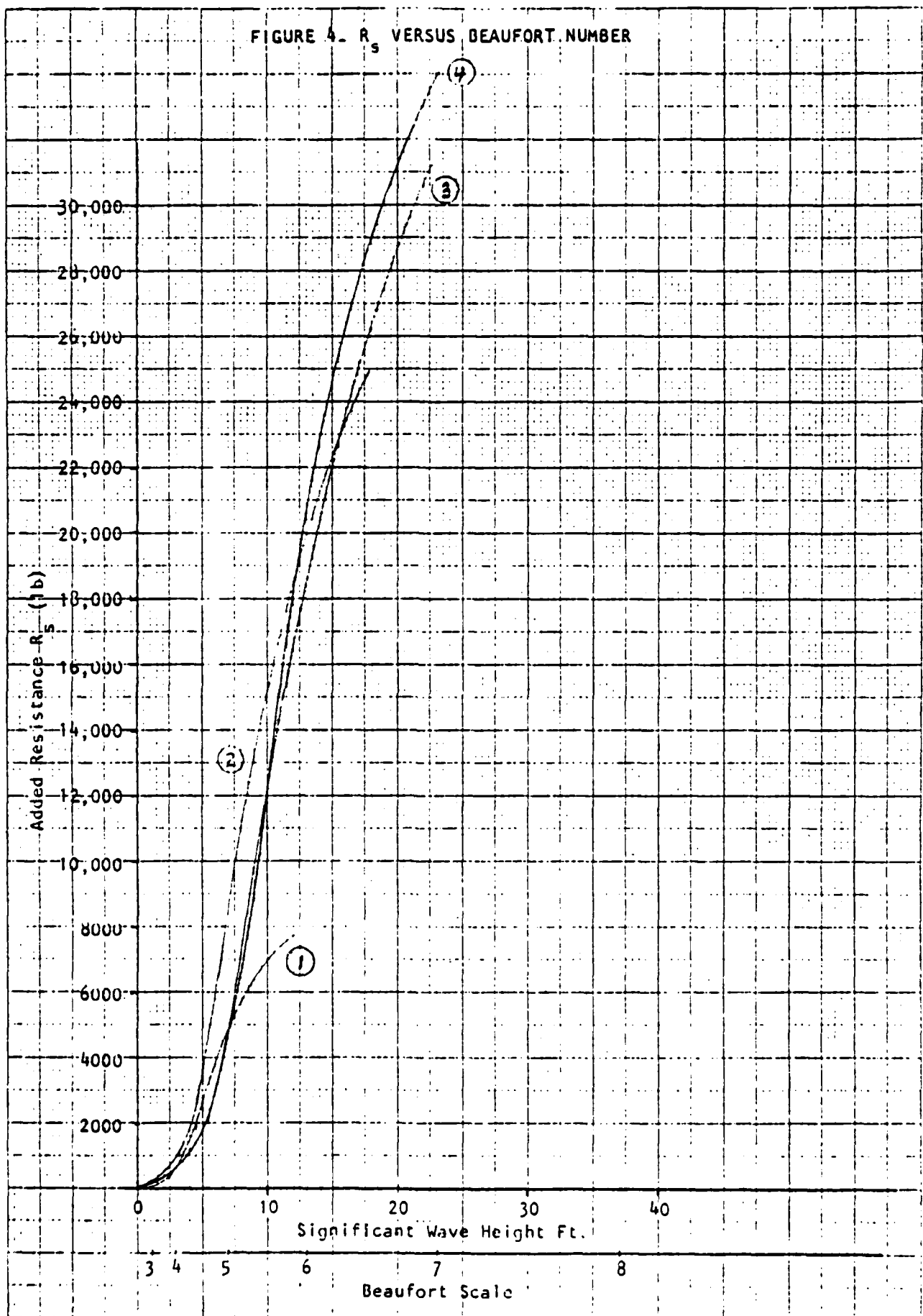
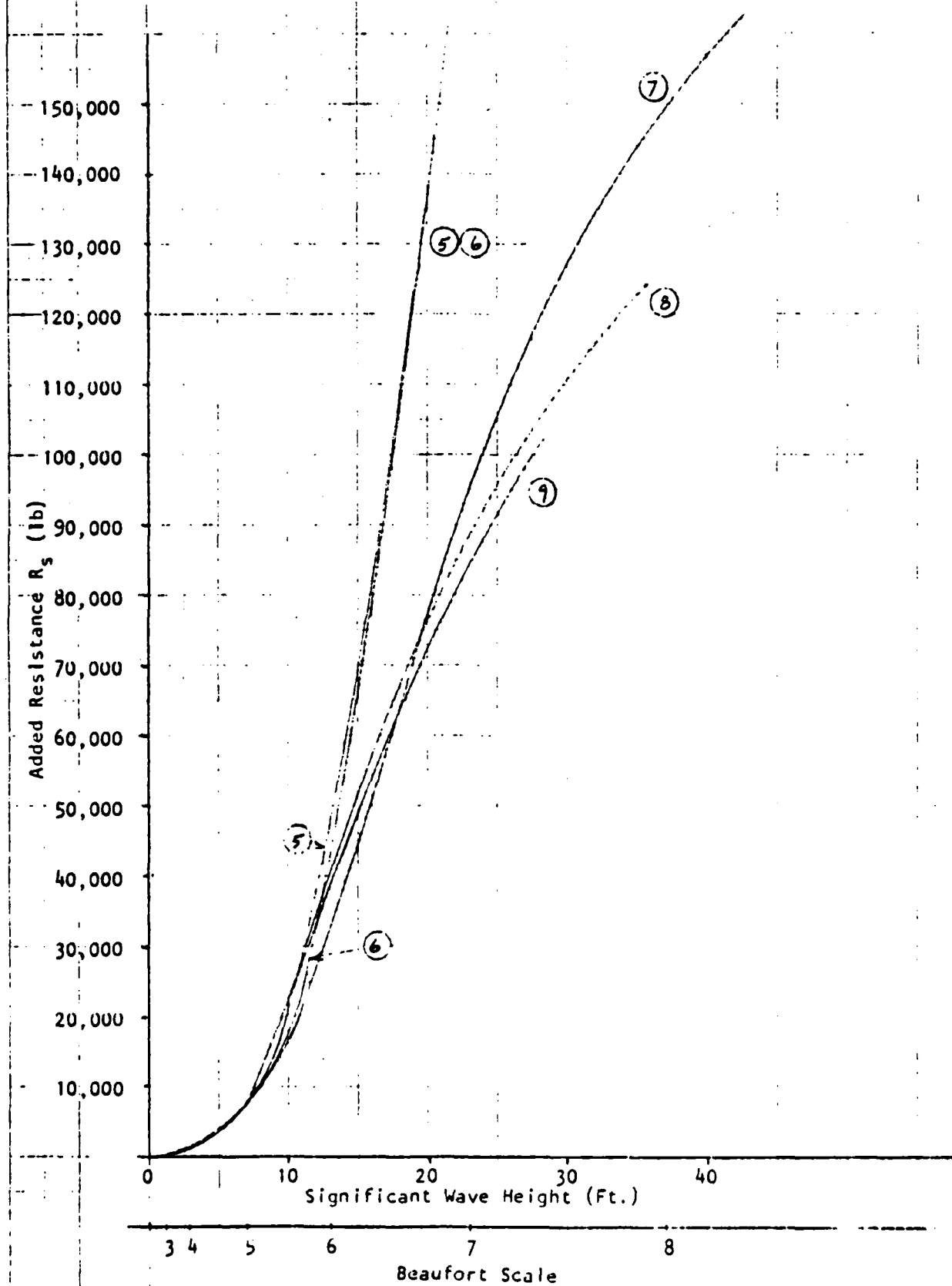


FIGURE 5. R_s VERSUS BEAUFORT NUMBER

46 1512

K-E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 6

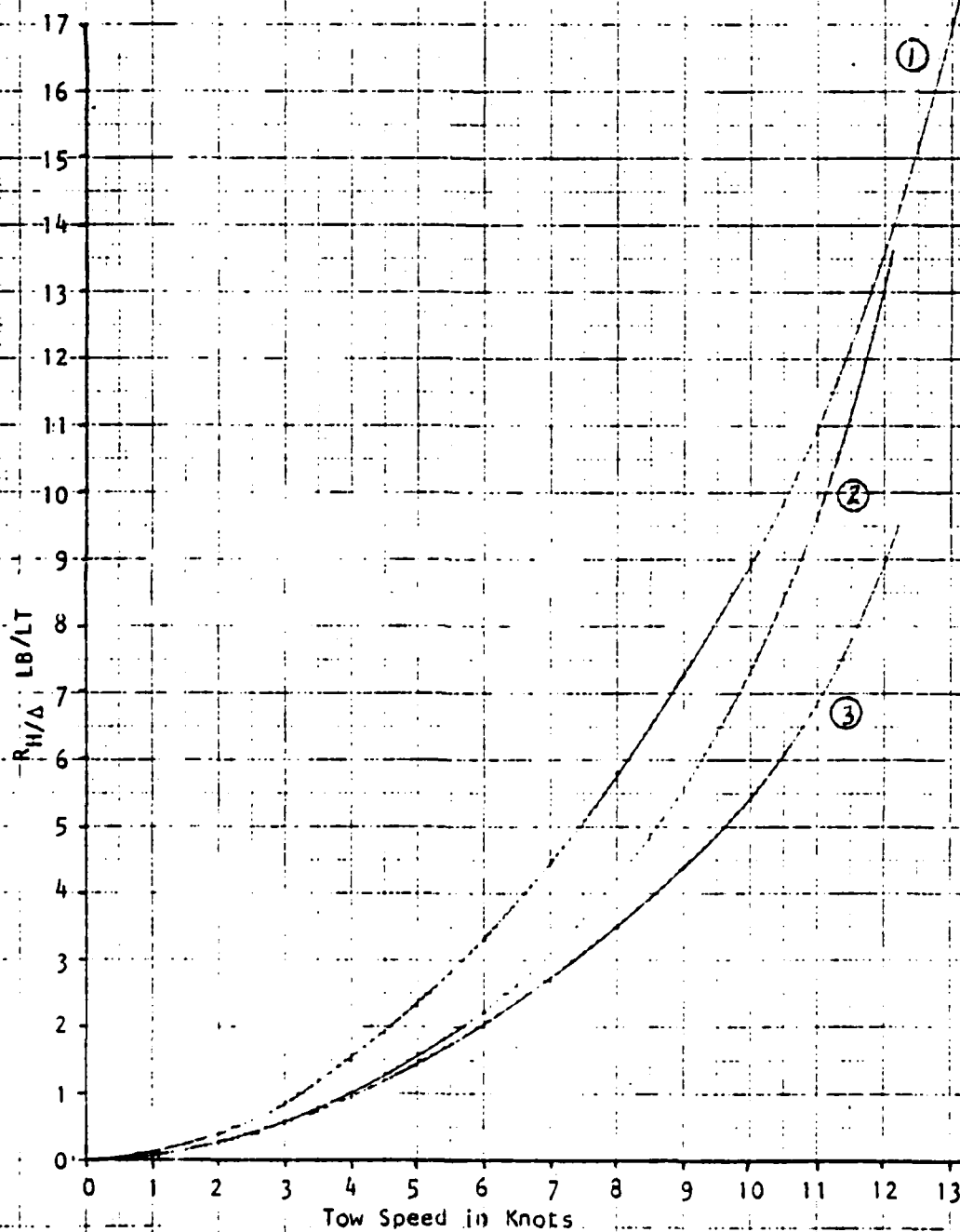
 R_H/Δ VERSUS TOW SPEED
(Curves 1 through 3)

FIGURE 7.

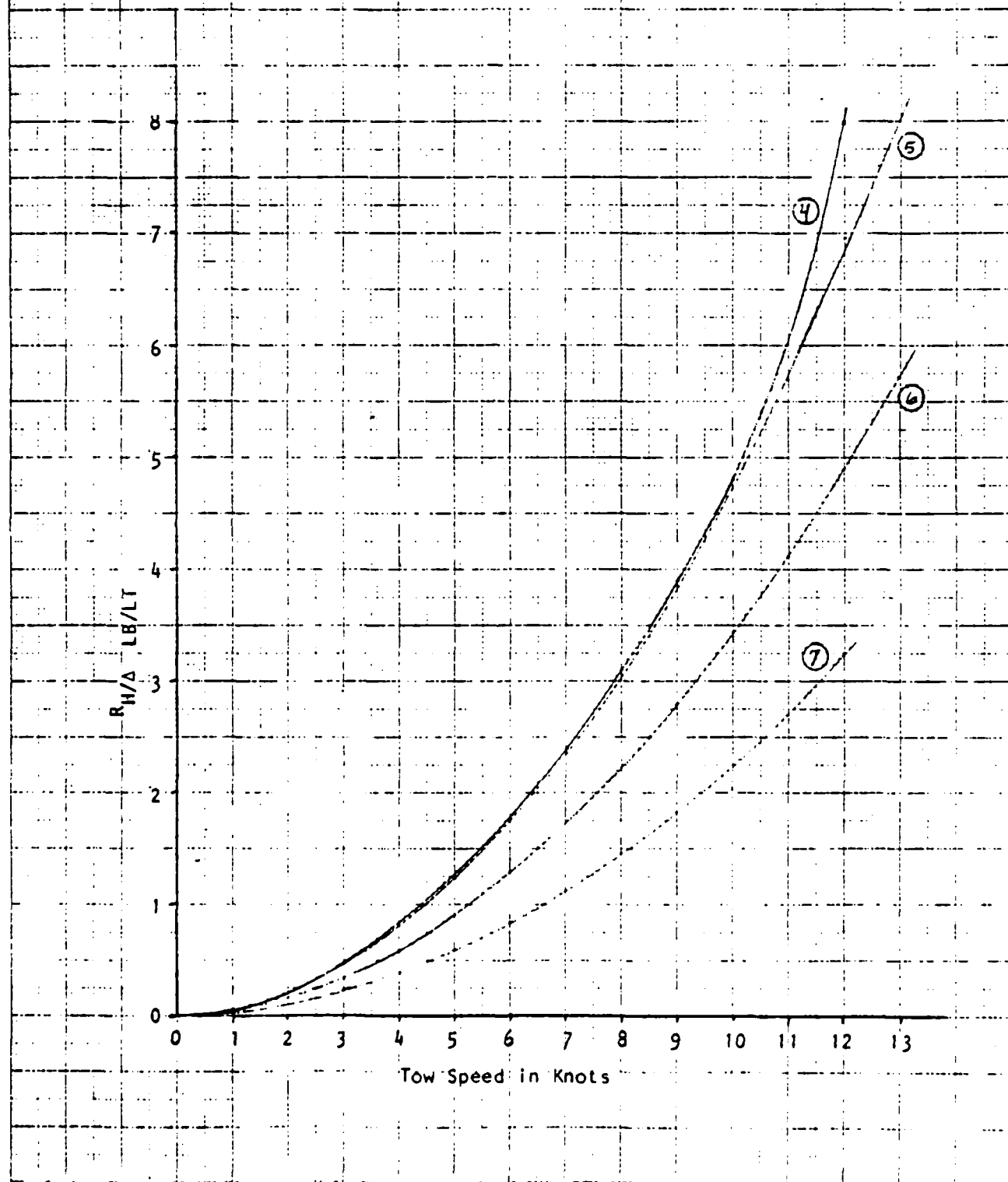
 R_H/Δ VERSUS TOW SPEED
(Curves 4 through 7)

FIGURE 8.

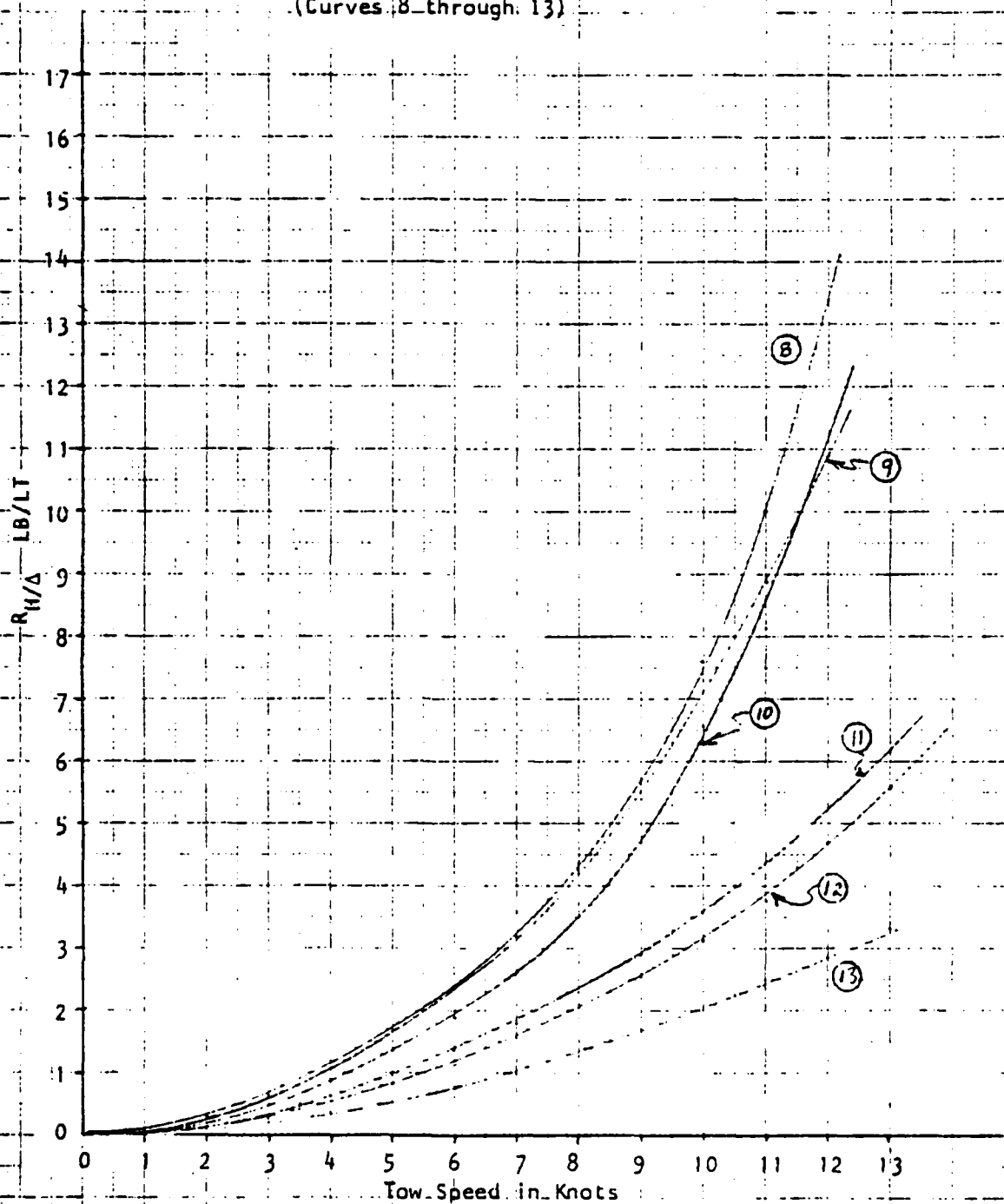
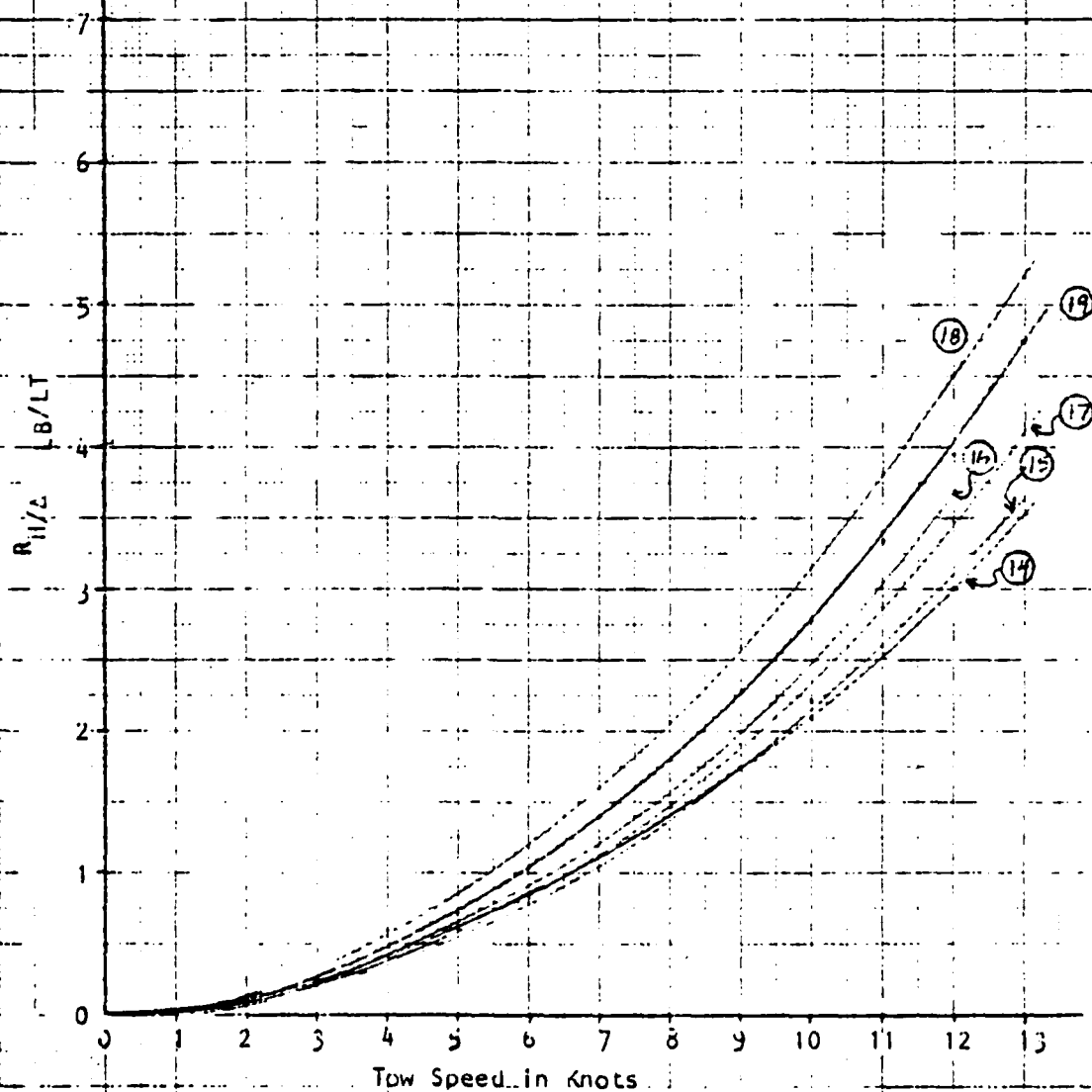
 R_H/Δ VERSUS TOW SPEED
(Curves 8 through 13)

FIGURE 9.

$R_{H/\Delta}$ VERSUS TOW SPEED
(Curves 14 through-19)



46 1512

K-E 10 X 10 TO THE CENTIMETER 10 X 25 CM
KLOPP & LISKER CO. MADE IN U.S.A.

FIGURE 10.

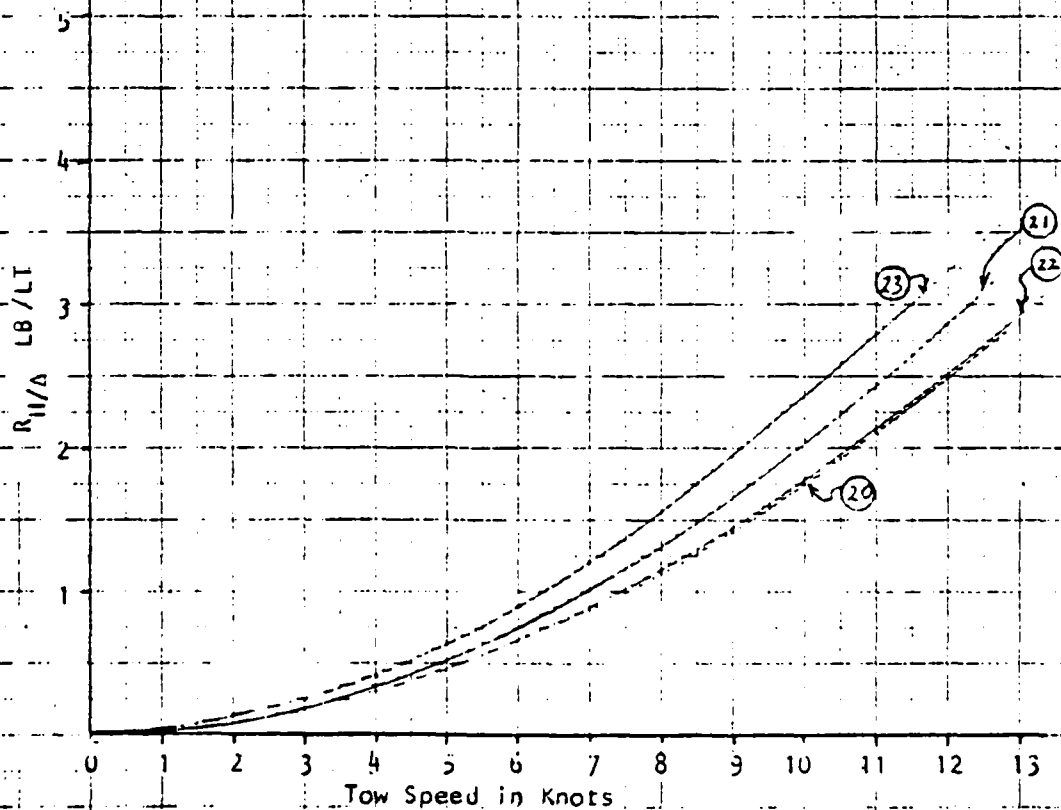
 R_H/Δ VERSUS TOW SPEED
(Curves 20 through 23)

FIGURE 11
 $R_{H/\Delta}$ VERSUS TOW SPEED
 (Curves 24 through 28)

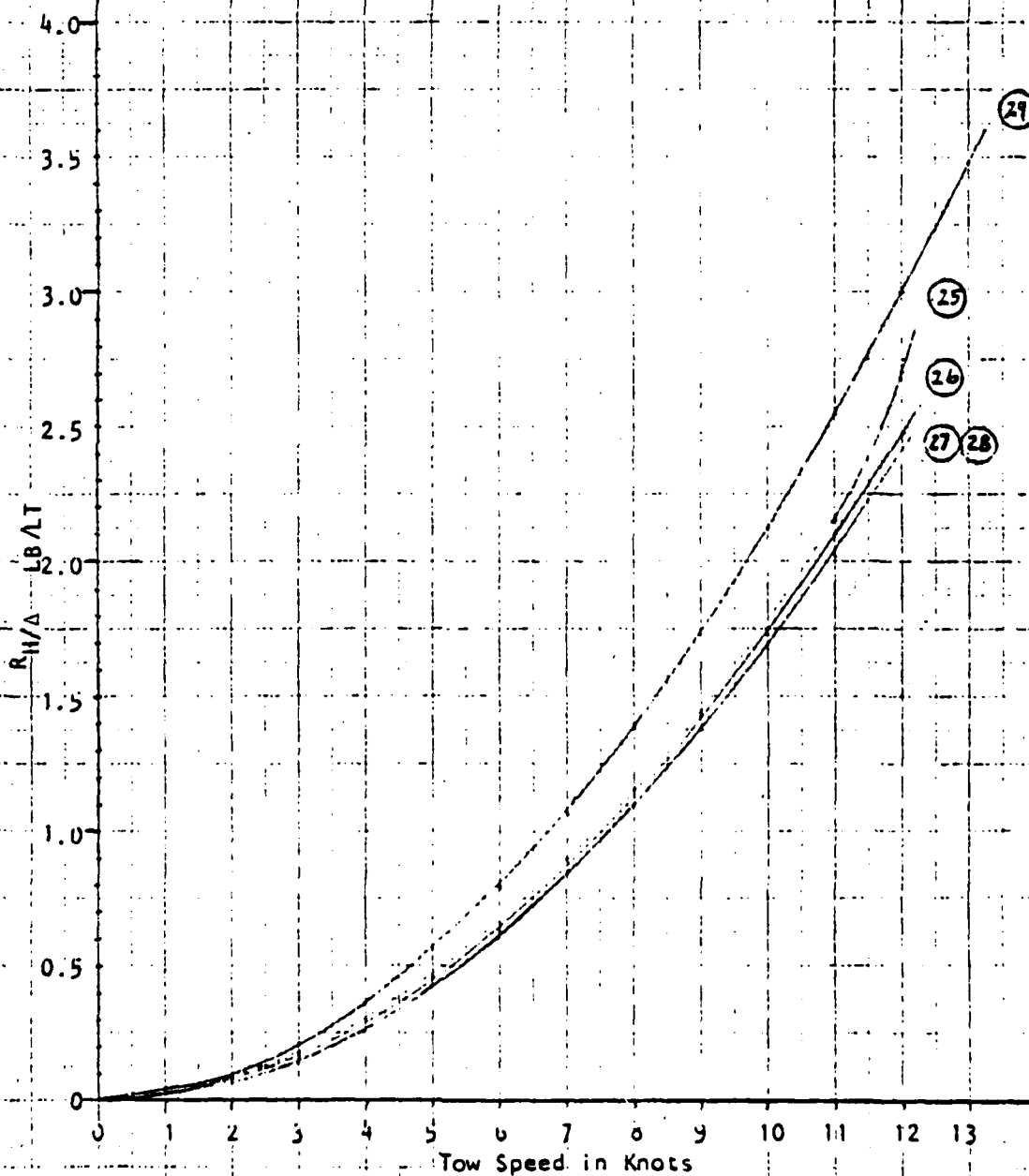
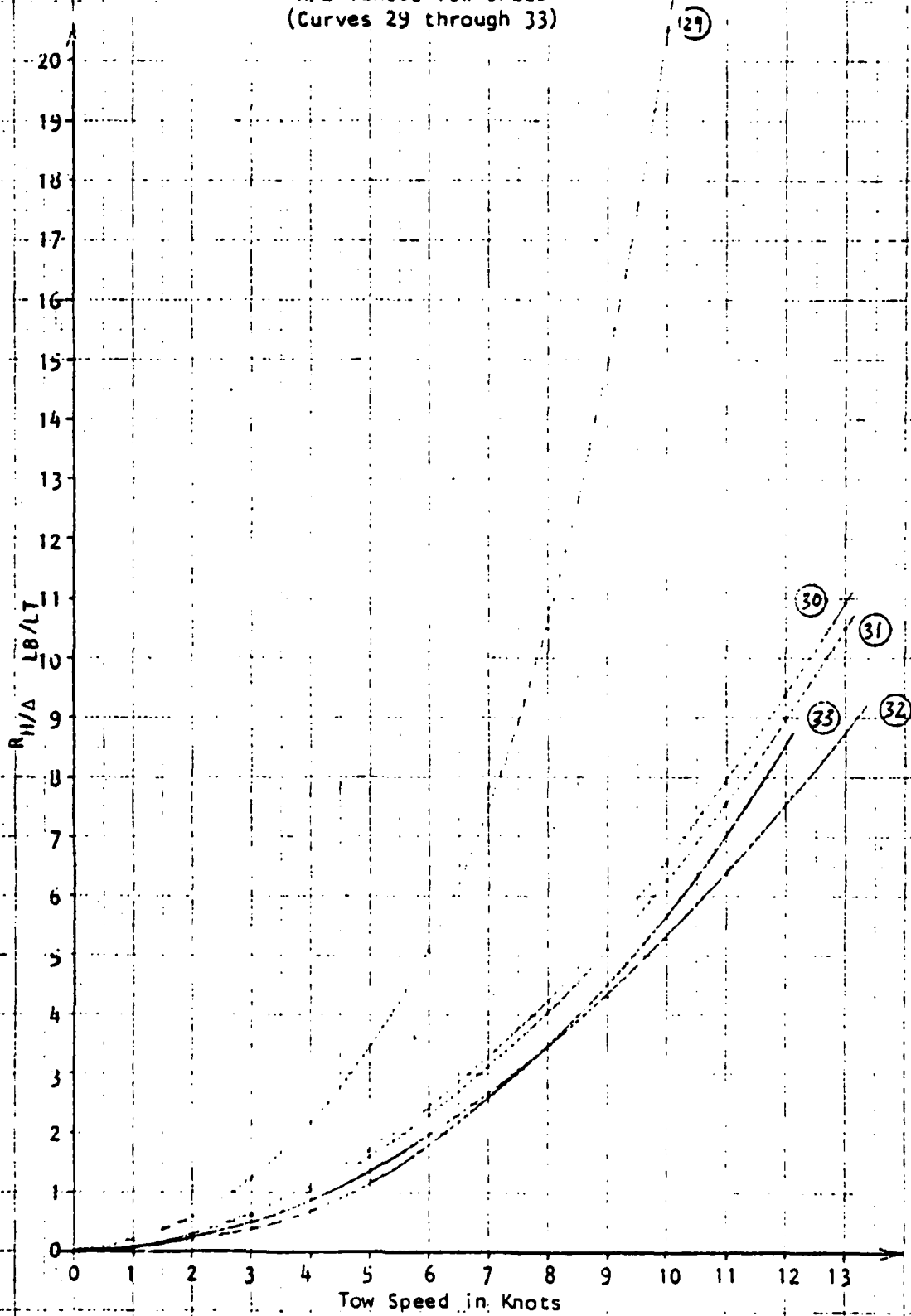


FIGURE 12

R_H/Δ VERSUS TOW SPEED
(Curves 29 through 33)



K&E 10 X 10 TO THE CENTIMETER 46 1512
13 X 35 CM
KUPPALL & LANE CO

FIGURE 12

R_H/Δ VERSUS TOW SPEED
(Curves 29 through 33)

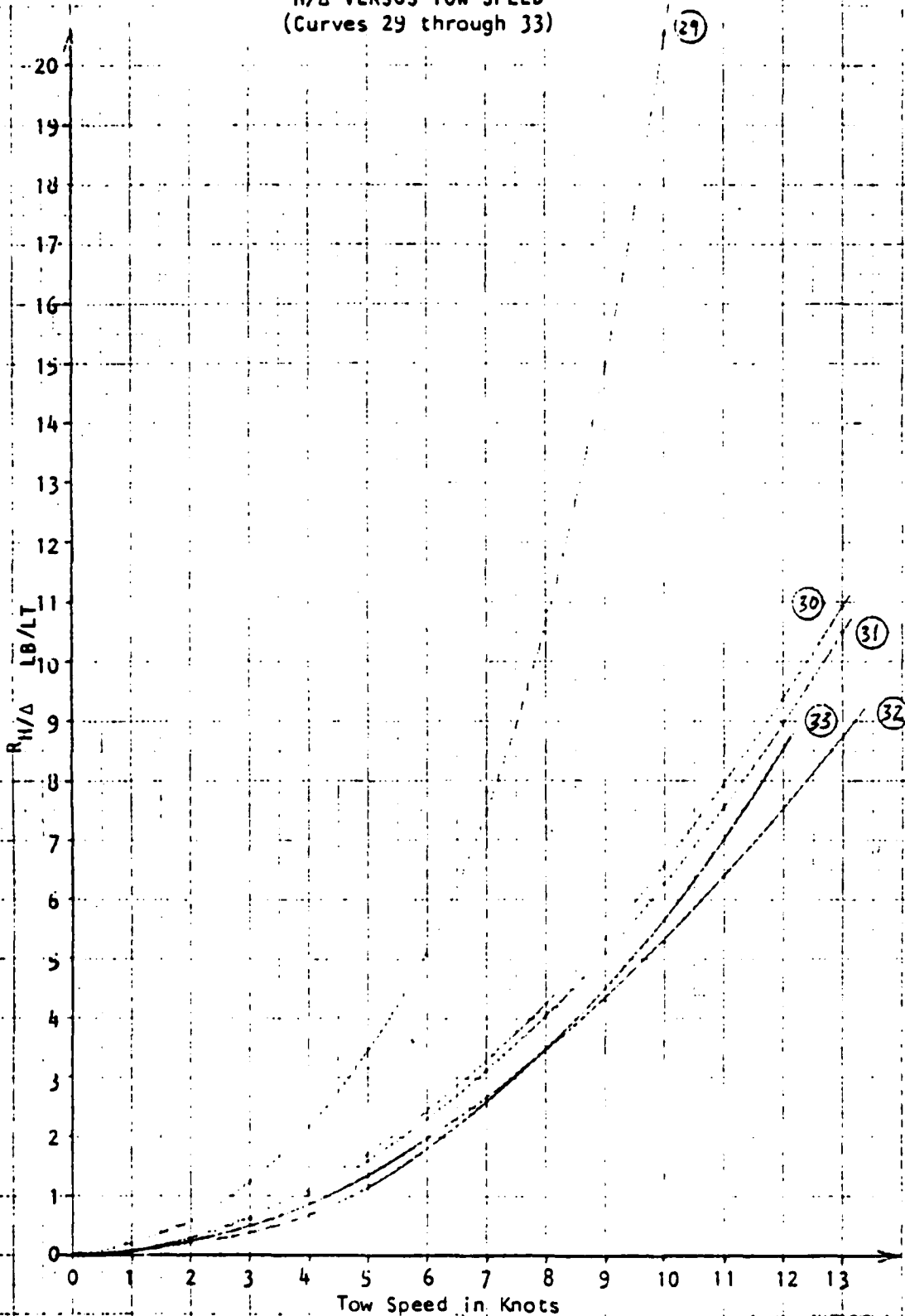
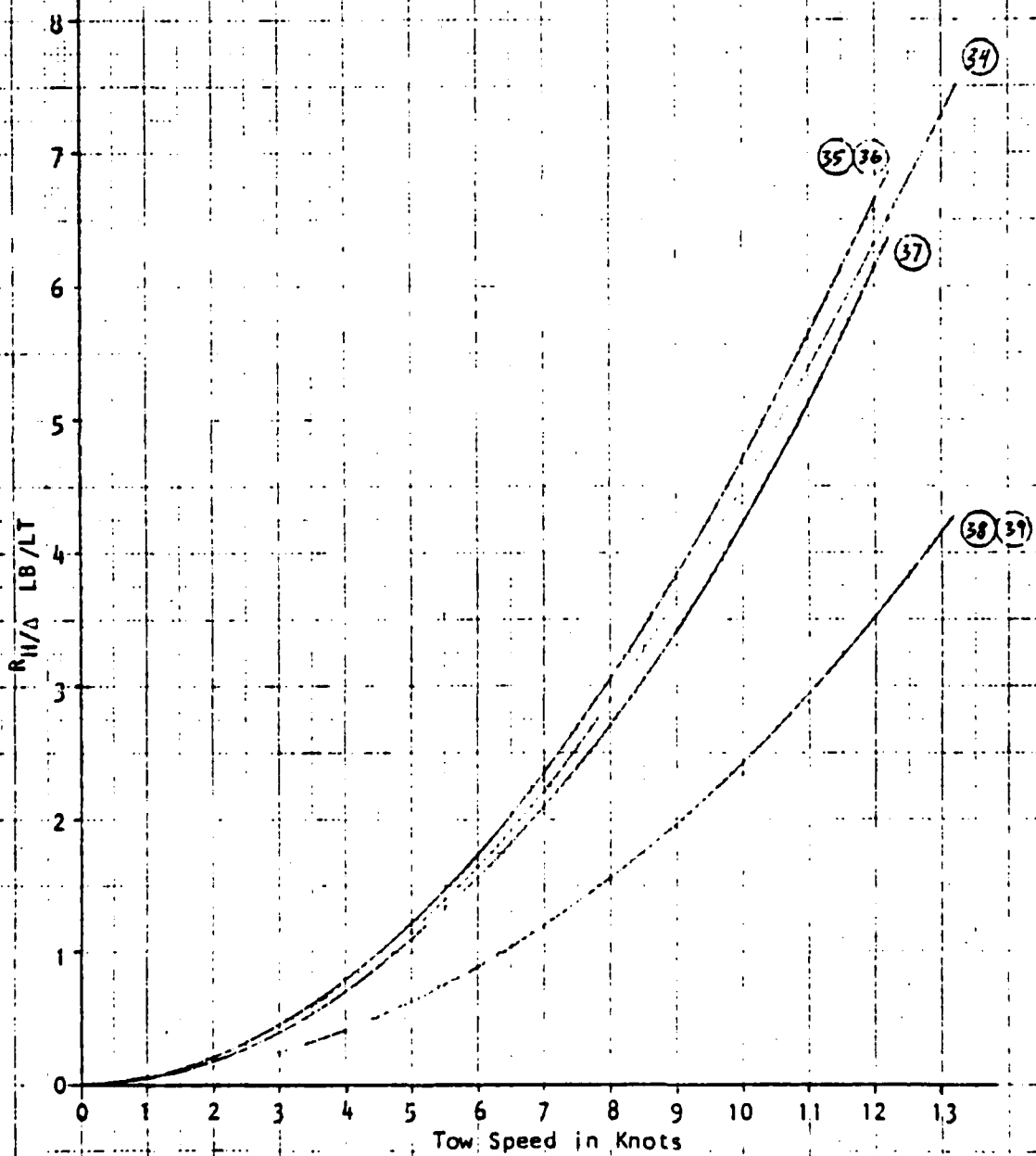


FIGURE 13

R_H/Δ VERSUS TOW SPEED
(Curves 34 through 39)



conducted in procedure for tow resistance to the U.S. Navy calculation. The study is conducted in two steps. In the first step, the study is performed using both the U.S. Navy method and the MR&S for eight ships for which complete data exists. Each method is separated into the four resistance components: hull resistance, wave resistance, air resistance, and propeller resistance. Three Beaufort numbers and three sea state and wind resistance. The resulting data were examined for each of three tow speeds. The results are presented in Table 8-1.

The second part of the study compares the actual towline tensions measured in full scale tests with the resistance obtained for the U.S. Navy calculation procedures. Several towing tests have been conducted and MR&S calculation of these tests is sufficient to permit correlation for but documentation of these tests is not available, it would be only the LST 1179 class. As more data becomes available, it would be beneficial to extend this part of the correlation study.

8.2 Results of Correlation Study

8.2.1 Part I Comparison of MR&S and U.S. Navy Methods of Calculation

A comparison of the MR&S and U.S. Navy calculations is done for each component of resistance as shown in Table 8-1. The differences in hull resistance are quite large, sometimes varying by a factor of three. The effect of this difference on the total tow resistance can be seen by comparing the total resistance

Table 8-1 CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
AFT-148 OCEAN TUG	10	10.0	0	0	1821	14866	14594	16069	0	0	360	455	16775	31390	47%
	8	21.5	0	4	1213	7035	9340	10284	4221	900	1080	2105	15854	20324	22
	8	19.82	30	4	"	"	"	"	"	"	840	2022	15614	20241	23
	8	10.87	90	4	"	"	"	"	"	"	0	54	14774	18273	20
	5	29.5	0	6	2309	3664	3649	4017	-	23500	2848	3963	-	35144	-
	5	28.7	30	6	-	"	-	"	-	"	-	4239	-	35419	-
AOR-1 OILER	5	23.98	90	6	-	"	-	"	-	"	-	262	-	31443	-
	10	10.0	0	0	40354	66675	92996	102394	0	0	2277	3841	135627	72910	22
	8	21.5	0	4	24303	53340	59517	65532	33528	1300	6831	17753	124179	36625	9
	8	19.82	30	4	"	"	"	"	"	"	3795	15690	12143	35862	9
	8	10.87	90	4	"	"	"	"	"	"	0	4538	117348	124710	6
	5	23.5	0	6	3421	21908	23249	25598	16002	47500	12903	33422	55572	128428	57
AOE-1 FAST COMBAT SUPPORT	5	28.7	30	6	"	"	"	"	"	"	8349	32900	51021	127906	60
	5	73.98	90	6	"	"	"	"	"	"	0	442	42672	95447	55
	10	10.0	0	0	32834	118590	154766	170407	0	0	2925	3700	190525	292697	35
	8	21.5	0	4	18870	77050	99050	109061	47168	1300	7800	17103	172888	204514	15
	8	19.82	30	4	"	"	"	"	"	"	4875	16425	169963	203836	17
	8	10.87	90	4	"	"	"	"	"	"	0	393	165088	187804	12
AOE-1 FAST COMBAT SUPPORT	5	29.5	0	6	4188	77050	38692	42602	25728	44000	16575	32200	85183	195852	56
	5	28.7	30	6	"	"	"	"	"	"	9750	34440	78358	198092	60
	5	23.98	90	6	"	"	"	"	"	"	0	1915	68608	165567	58

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH
THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECT & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
FF 140 ESCORT	10	10.0	0	0	25817	31237	44461	48955	0	0	1715	607	71993	80799	11%
	8	21.5	0	4	14045	17850	28459	31331	17000	600	2573	2808	62073	52589	-18
	8	19.82	30	4	"	"	"	"	"	"	2058	2863	61558	52644	-17
	8	10.87	90	4	"	"	"	"	"	"	0	3445	59500	50126	-19
	5	29.5	0	6	5205	6630	11115	12238	9792	20800	4116	5286	30228	44954	33
	5	28.7	30	6	"	"	"	"	"	"	3430	6004	29542	45672	35
	5	23.98	90	6	"	"	"	"	"	"	0	1677	26112	41344	37
AF 58 STORES SHIP	10	10.0	0	0	19824	61031	35976	39612	0	0	1322	1672	57122	102315	44
	8	21.5	0	4	12625	39719	23025	25352	14260	1500	3965	7727	53875	74298	27
	8	19.82	30	4	"	"	"	"	"	"	2203	7421	52113	73992	30
	8	10.87	90	4	"	"	"	"	"	"	0	1580	49910	68151	27
	5	29.5	0	6	1856	16081	8994	9903	6510	41000	7489	14548	24849	81532	70
	5	28.7	30	6	"	"	"	"	"	"	4846	15560	22206	82544	73
	5	23.98	90	6	"	"	"	"	"	"	0	7690	17360	74674	77
CA 139 HEAVY CRUISER	10	10.0	0	0	72529	59848	109966	121079	0	0	4500	1594	186995	182521	-2
	8	21.5	0	4	47708	30058	70377	77490	47234	1300	6750	7368	172069	116216	-48
	8	19.82	30	4	"	"	"	"	"	"	5400	7514	170719	116362	-47
	8	10.87	90	4	"	"	"	"	"	"	0	904	165319	109752	-50
	5	29.5	0	6	17596	15566	27491	30270	27052	32500	10800	13871	82939	92207	10
	5	28.7	30	6	"	"	"	"	"	"	9000	15755	81139	94091	14
	5	23.98	90	6	"	"	"	"	"	"	0	4399	72139	82735	13

Table 8-1 (Cont'd)

[illegible]

values for a zero Beaufort number since the values for propeller resistance are within eleven per cent of each other. The differences in hull resistance result from a small data base used in the U.S. Navy towing manual. Only five resistance curves exist to apply to all ship classes whereas the MR&S method has 39 resistance curves. The biggest differences occur with ships like the ATF-148 or the AOE-1 which do not seem to fit any of the five ship classifications used in the towing manual.

The MR&S calculation for propeller resistance always yields value eleven per cent higher than the method from the towing manual since the equation for propeller resistance is the same but the MR&S coefficient is eleven per cent greater than that from the towing manual. One difference between the two methods which is not evident in the correlation study is that in the MR&S method, propeller resistance is separate from hull resistance so it is not a function of ship displacement. Thus the total propeller projected area, which can vary greatly even among similar ships, is accurately accounted for.

There is very poor correlation between the two methods of calculation for sea state resistance. The reason for the discrepancy is that in the Navy method the sea state factor K_1 is a percentage of the calm water resistance which is not correct as demonstrated by Marou's work (Ref.27). The K_1 factor is also multiplied by the propeller resistance which should not be involved in the correction for sea state. The MR&S method presents nine curves for the added resistance in waves which is added to the calm water resistance. Only one ship speed was used for each curve but this is considered a reasonable simplification since added resistance in waves

does not vary greatly over the speed range considered. Note that the added resistance in waves decreased greatly as the Beaufort number increased from 4 to 6 in the Navy calculation. This is a result of the reduction in speed which causes a significant change in calm water resistance. If the Beaufort remained the same, as ship speed decreased the actual added resistance would probably increase for low significant wave heights but the method in the towing manual would indicate a substantial decrease in added resistance. The MR&S calculation for added resistance in waves appears to yield more consistent results.

The results of the MR&S calculation for wind resistance are always greater than those of the towing manual, in some cases by a factor of three. Since documentation for the development of the calculation procedure in the towing manual was not available, it is not possible to fully explain this discrepancy. Use of the K factor in the MR&S method produces a longitudinal force with a beam wind while the method in the towing manual always produces a force of zero for a beam wind. The difference in wind resistance generally amounts to less than eight per cent of the total resistance. When more wind tunnel data becomes available it may be possible to reduce the factors of safety used in the present calculation.

All of the differences of the individual resistance components above

combine together to produce the differences in total tow resistance.

The per cent difference ranges from 2% to 77%.

8.2.2 Part 11-Comparison of Calculation Procedures with Full Scale Tests

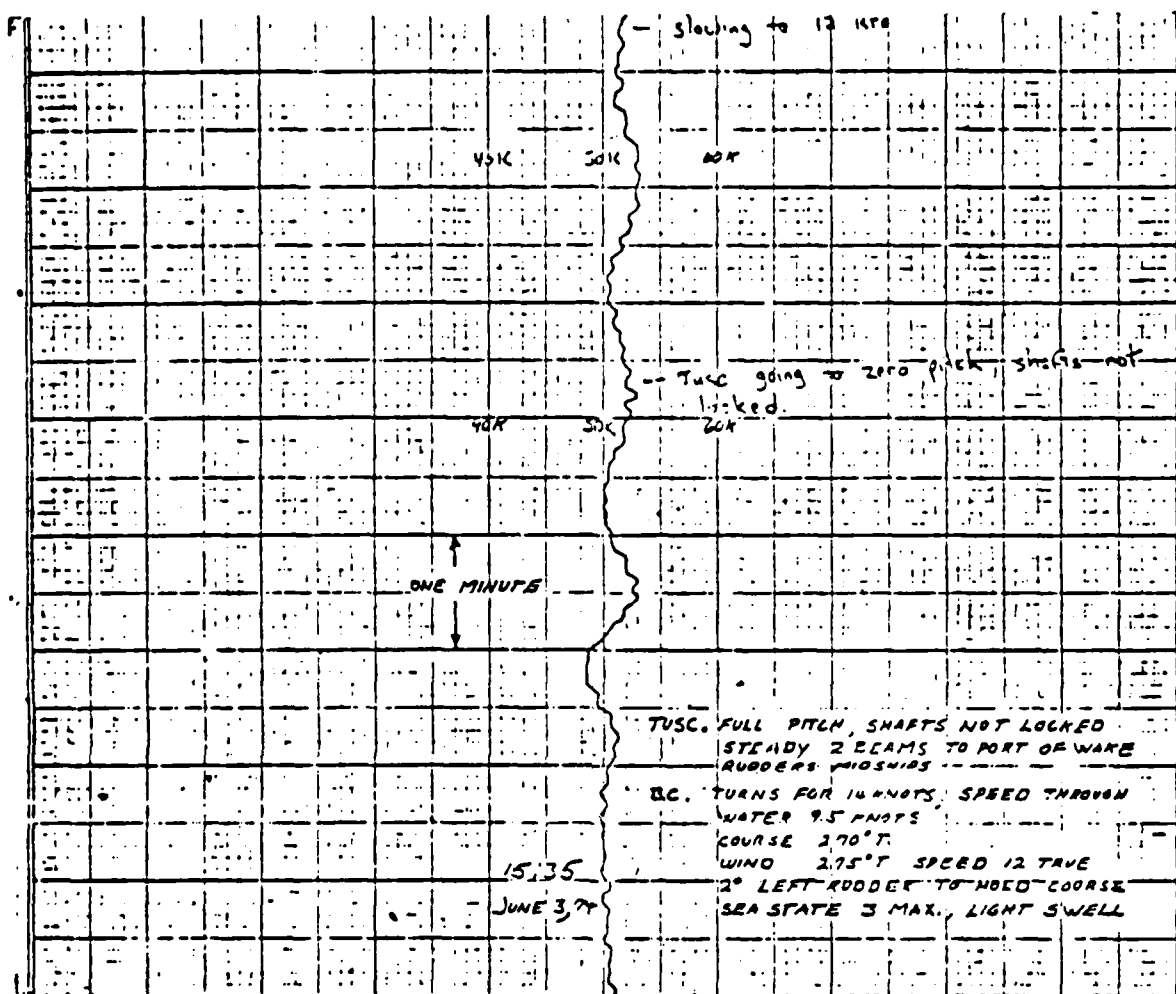
Results were obtained from full scale towing tests of the LST 1179 class for several tow conditions (Ref. 28). Two straight line towing tests were used since direct correlation could be made between these tests and the results of the calculation procedures. The shaft was not locked during the test runs but observers on board the tow noted the shafts never rotated due to the friction of the shafting and gears. Thus the calculations for locked propeller drag are valid. Figures 8-1 and 8-2 provide the data obtained during tests number 1 and 2 respectively. Table 8-2 summarizes the results.

Table 8-2. Summary of Results for Tests #1 & #2 of LST 1179 Class

Test No.	Tow Speed KT.	Rel. Wind Speed KT.	Rel. Wind Dir. Deg.	Measured Tow Resis. Lb. LST 1187 Test (Average)	MR&S Calc. Tow Resis.		U.S.N. Calc. Tow Resis.	
					LB.	% Diff.	LB.	% Dif.
1	9.5	21.48	3	51,000	74234	45	108946	114
2	9	1.44	175	48,000	60990	27	92263	92.2

TEST #1

TOWING AT HIGH SPEED, STRAIGHT COURSE



B.C. TURNS FOR 14 KNOTS
 PIT LOG - 9.5 KNOTS
 6-ENGINES
 COURSE 270° T
 WIND 275° T SPEED 12 KNOTS TRUE
 2° LEFT RUDDER TO HOLD COURSE
 SEA STATE 3 MAX, LIGHT SWELL

TUSC. FULL PITCH, SHAFTS NOT LOCKED
 STEADY 2 BEAMS TO PORT OF WAKE
 RUDDERS 0 DEGREES

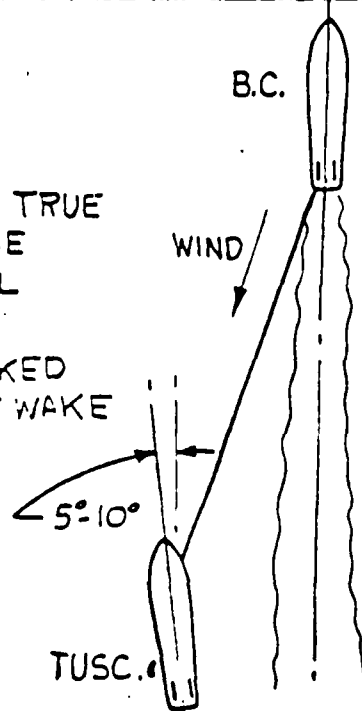
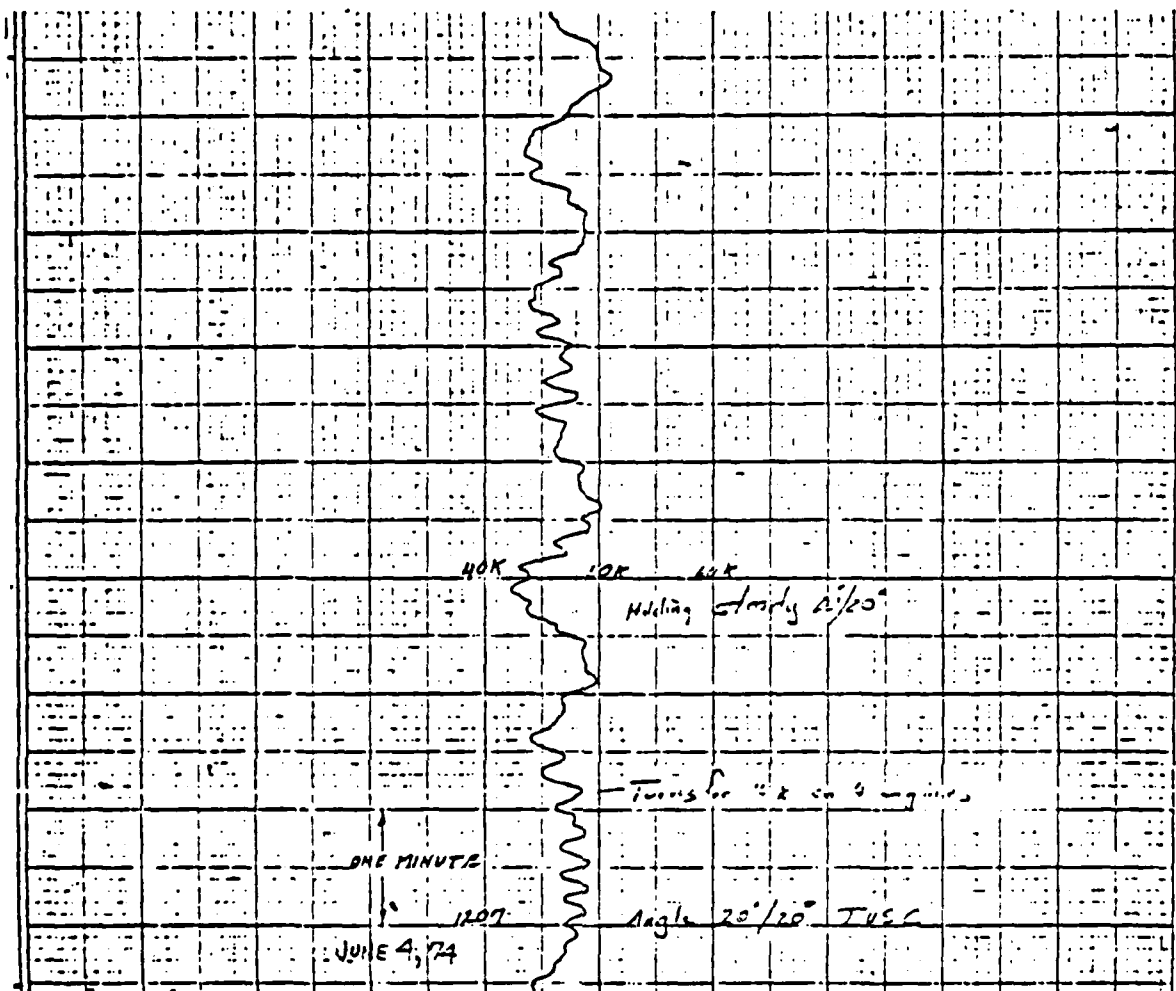


FIGURE 8-1 (Ref. 28)

TUSC.

TEST #2

TURNS FOR 14 KNOTS DOWN WIND



B.C. TURNS FOR 14 KNOTS
 PIT LOG 9 KNOTS
 4 ENGINES
 COURSE 070°T
 WIND 254°T SPEED 10 KNOTS TRUE
 SEA STATE 3 MAX LIGHT SWELL
 RUDDER 4° LEFT TO HOLD COURSE

TUSC FULL PITCH, SHAFTS NOT LOCKED
 RUDDERS 0 DEGREES

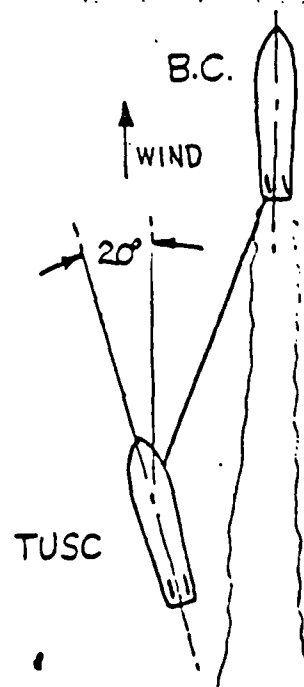


FIGURE 8-2 (Ref. 28)

9. Conclusions

This study has examined the four basic components of tow resistance, hull, propeller, wind and sea state and has combined these components into a calculation procedure for tow resistance. As described in section 2, other factors such as yaw and surge may exist which are not considered in the proposed calculation procedure. These additional factors could significantly increase the tow resistance and should be considered in future studies. No factor of safety has been applied to the final tow resistance since the individual resistance components all have a conservative margin built into them.

The calculation procedure for tow resistance developed in this study is somewhat more complex than the procedure in the present towing manual (Ref. 8) but has the advantages of being more rigorous and fully documented. The biggest difference between the two methods is that calm water hull resistance is considered separately from the propeller resistance unlike the present towing manual which presents the two resistance components together as one curve. The disadvantage of combining hull and propeller resistance on one plot of resistance divided by ship displacement versus speed is that propeller resistance appears to vary with displacement which is not true. With the components combined, it is not possible to disregard the propeller resistance if a ship is towed without propellers. The calculation for propeller resistance derived in this study is quite similar to that used in the Navy towing manual except that the propeller coefficient was increased slightly on the basis of available model tests. The calculation for wind resistance developed in this study is based on the procedure used in powering prediction of U.S. Naval ships (Reference 14) with a few modifications. The advantage

of this method over that used in the current towing manual is that it more rigorously accounts for the effect of heading angle relative to the wind. The sea state factor K_1 as used in the towing manual was eliminated and was replaced by a set of curves of added resistance in waves versus Beaufort number and significant wave height. These curves of added resistance are independent of the propeller resistance and of the calm water resistance. This change should result in more realistic results than were obtained from the calculation procedure currently in use.

The correlation study indicates that significant differences exist between the results obtained from the calculation procedure developed in this report and the U.S. Navy Towing Manual currently in use. The available full scale tow resistance data is too limited to draw final conclusions, but the data obtained thus far indicates that the MR&S calculation procedure yields conservative but more accurate results than the method used in the current U.S. Navy Towing Manual. As additional full scale results become available, it should be possible to make the present calculation procedure less conservative.

10. Recommendations

The calculation procedure for the determination of tow resistance shown in section 7 was developed within the limited scope of the subject task. Further research and development can be undertaken to improve the accuracy of this calculation and extend its applicability. The following recommendations will vary in feasibility and cost.

10.1 Full Scale Tow Resistance Tests

Full scale tow resistance tests are the most effective means of checking the accuracy of the proposed calculation procedure. Full scale tests in calm water would yield valuable information on the magnitude of locked propeller drag since small scale tank tests lose some accuracy due to scaling effects. Tests should be conducted in a range of weather conditions and relative wind headings to determine the accuracy of assumptions made in the calculations for wind resistance and added resistance in waves.

10.2 Inclusion of Additional Parameters

Additional parameters as discussed in section 2 could be included in an extended study. The problem of calculating tow resistance should be considered as a three dimensional rather than two dimensional problem so all six degrees of motion are considered. The increase of resistance while turning is another significant parameter to consider.

10.3 Work on Existing Parameters

Additional research could be conducted on the parameters examined in this study. More hull resistance curves could be added to more accurately define the hull resistance of the naval fleet. In particular, curves for

barges and submarines could be included. The problem of submarine resistance is particularly difficult since submarines are directionally unstable and show a great tendency to yaw while being towed.

The method for determining added resistance in waves used in this study is approximate and can be improved by calculating curves for more ship classes for a range of tow speeds. Instead of assuming a series 60 hull form, computer programs can be used to calculate added resistance for the specific hull shapes considered and in particular would consider transome stern ships. More accurate results would be possible if a two parameter study including wave period as well as significant wave height were used.

The wind resistance is a small component of the total resistance, generally less than 12 percent. However, additional work could be performed to increase the accuracy of this calculation. The most important improvement would be to calculate for a number of ships the additional drag due to yaw which is a function of the relative wind angle and immersed lateral area. Presently this additional drag is assumed to be fifty percent of the wind resistance for all relative wind angles and is based on very limited data.

10.4 Digital Simulations

The most elegant solution to the tow resistance problem would utilize simulation studies based on data from captive model tests. Work has already been done in this area as described in reference 29 where a Continuous System Modeling Program (CSMP) was used to study a tow trajectory versus time.

Using this approach towline forces could be determined for the actual motion of the tow (including yaw and sway motions) which is not considered in the simplified model used in this study. To be effective this would have to be performed for a large number of ships in varying sea conditions which would be quite costly.

11.

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FIGURE 10.

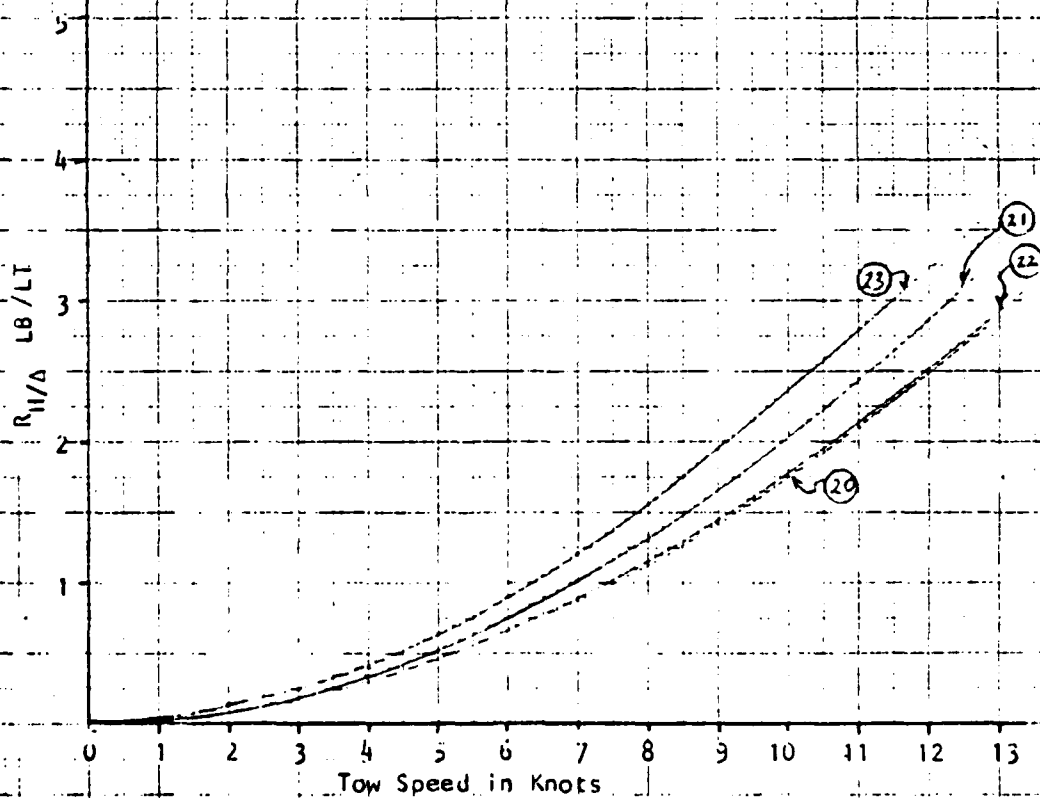
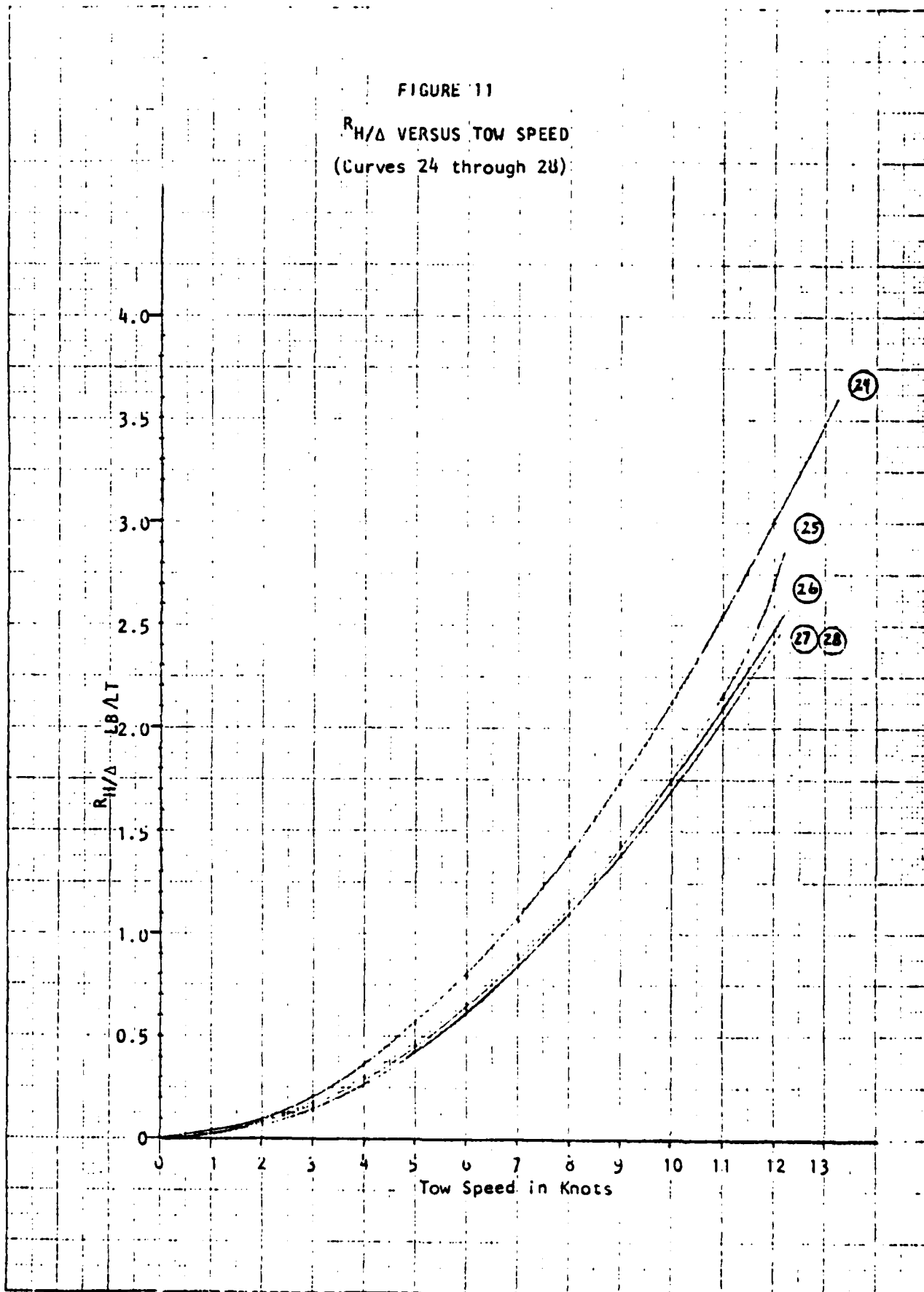
 R_H/Δ VERSUS TOW SPEED
(Curves 20 through 23)

FIGURE 11
 R_H/Δ VERSUS TOW SPEED
 (Curves 24 through 28)



K-E 10 V 10 TO THE CENTIMETER 46 1512
19 X 25 CM
KEUSFAL 3 L3541 9 CO

FIGURE 12

R_H/Δ VERSUS TOW SPEED
(Curves 29 through 33)

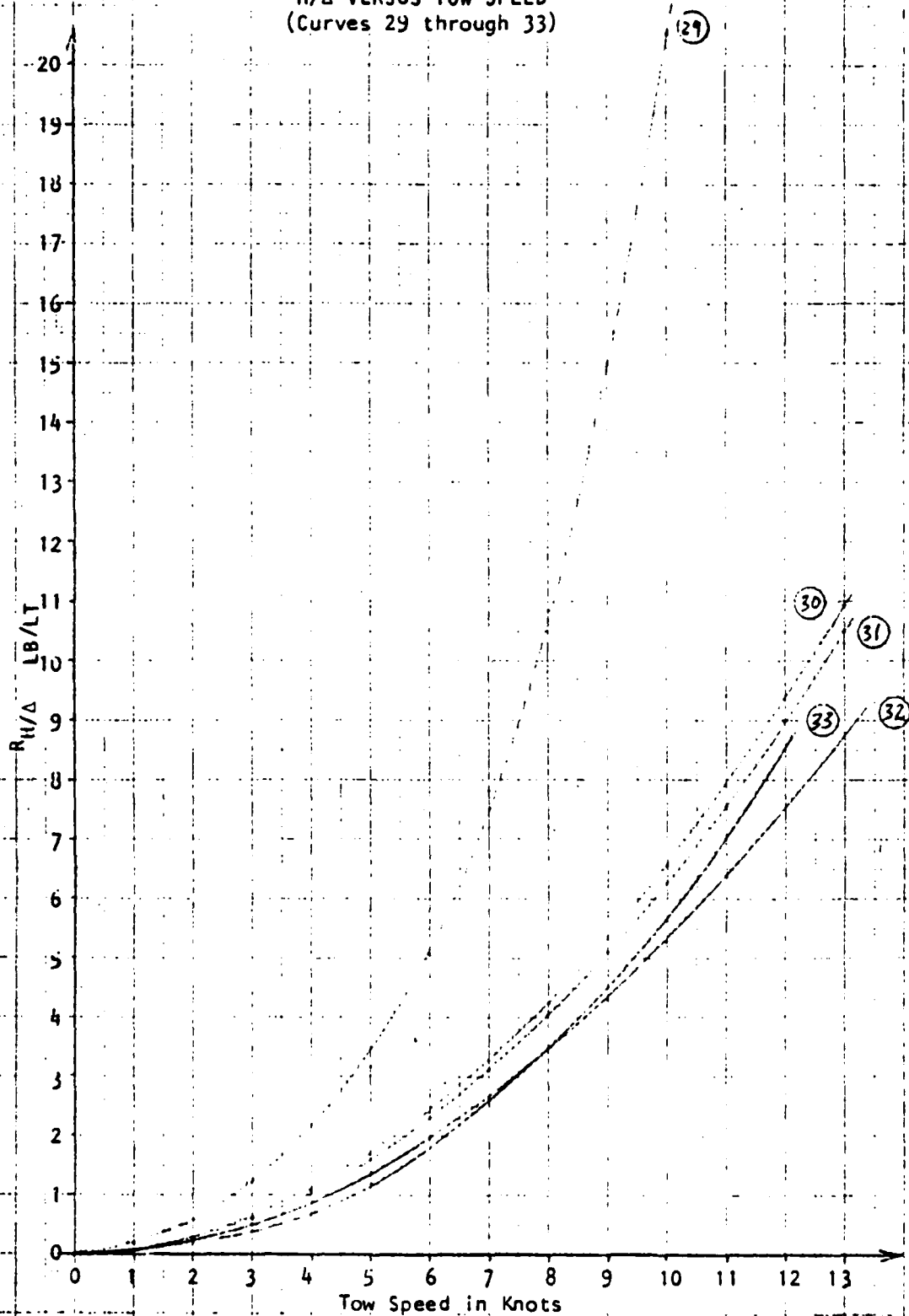


FIGURE 12
 $R_{H/\Delta}$ VERSUS TOW SPEED
 (Curves 29 through 33)

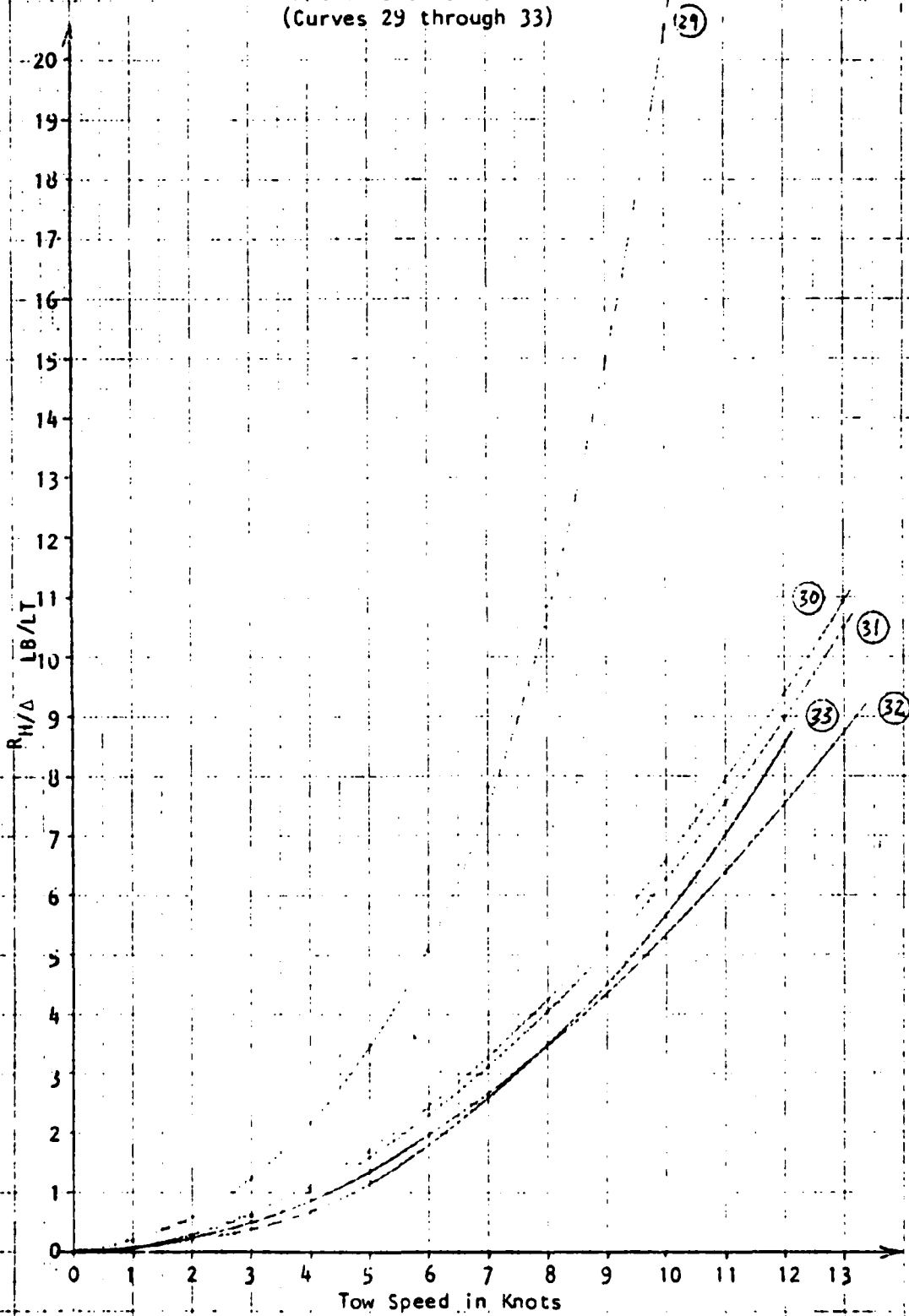
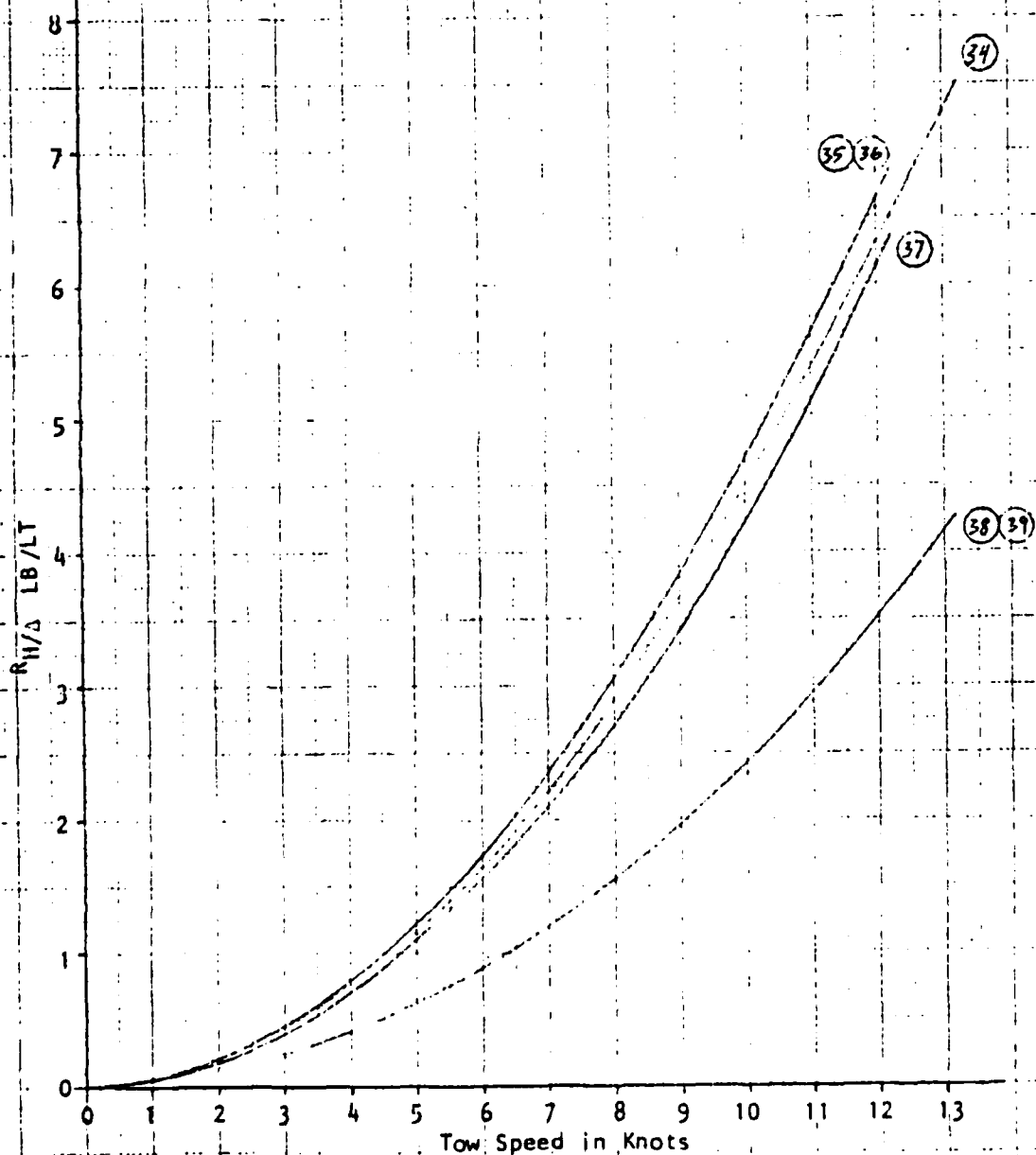


FIGURE 13

R_H/Δ VERSUS TOW SPEED
(Curves 34 through 39)



8. Correlation Study

8.1 Description of Study

A correlation study was conducted in an effort to verify the accuracy of the calculation procedure for tow resistance developed in this report and to compare it to the U.S. Navy calculation procedure which is currently in use. The study is conducted in two steps. In the first step calculations are performed using both the U.S. Navy method and the method developed by MR&S for eight ships for which complete data exists. The tow resistance for each method is separated into the four resistance components, hull, propeller, sea state and wind resistance. Three Beaufort numbers and three wind directions were examined for each of three tow speeds. The resulting data is presented in Table 8-1.

The second part of the study compares the actual towline tension measured in full scale tests with the resistance obtained for the U.S. Navy and MR&S calculation procedures. Several towing tests have been conducted but documentation of these tests is sufficient to permit correlation for only the LST 1179 class. As more data becomes available, it would be beneficial to extend this part of the correlation study.

8.2 Results of Correlation Study

8.2.1 Part I Comparison of MR&S and U.S. Navy Methods of Calculation

A comparison of the MR&S and U.S. Navy calculations is done for each component of resistance as shown in Table 8-1.

The differences in hull resistance are quite large, sometimes varying by a factor of three. The effect of this difference on the total tow resistance can be seen by comparing the total resistance

Table 8-1 CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECTION DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
AFT-148 OCEAN TUG	10	10.0	0	0	1821	14866	14594	16069	0	0	360	455	16775	31390	47%
	8	21.5	0	4	1213	7035	9340	10284	4221	900	1080	2105	15854	20324	22
	8	19.82	30	4	"	"	"	"	"	"	840	2022	15614	20241	23
	8	10.87	90	4	"	"	"	"	"	"	0	54	14774	18273	20
	5	29.5	0	6	2309	3664	3649	4017	-	23500	2848	3963	-	35144	-
AOR-1 OILER	5	28.7	30	6	-	"	-	"	-	"	-	4239	-	35419	-
	5	23.98	90	6	-	"	-	"	-	"	-	262	-	31443	-
	10	10.0	0	0	40354	66675	92996	102394	0	0	2277	3841	135627	172910	22
	8	21.5	0	4	24303	53340	59517	65532	33528	1300	6831	17753	124179	136625	9
	8	19.82	30	4	"	"	"	"	"	"	3795	15690	12143	135862	9
AOE-1 FAST COMBAT SUPPORT	8	10.87	90	4	"	"	"	"	"	"	0	4538	117348	124710	6
	5	29.5	0	6	3421	21908	23249	25598	16002	47500	12903	33422	55572	128428	57
	5	28.7	30	6	"	"	"	"	"	"	8349	32900	51021	127906	60
	5	73.98	90	6	"	"	"	"	"	"	0	442	42672	95447	55
	10	10.0	0	0	32834	118590	154766	170407	0	0	2925	3700	190525	292697	35
AOE-1 FAST COMBAT SUPPORT	8	21.5	0	4	18870	77050	99050	109061	47168	1300	7800	17103	172888	204514	15
	8	19.82	30	4	"	"	"	"	"	"	4875	16425	169963	203836	17
	8	10.87	90	4	"	"	"	"	"	"	0	393	165088	187804	12
	5	29.5	0	6	4188	77050	38692	42602	25728	44000	16575	32200	85183	195852	56
	5	28.7	30	6	"	"	"	"	"	"	9750	34440	78358	198092	60
SUPPORT	5	23.98	90	6	"	"	"	"	"	"	0	1915	68608	165567	58

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECTION DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
FF 140 ESCORT	10	10.0	0	0	25817	31237	44461	48955	0	0	1715	607	71993	80799	11%
	8	21.5	0	4	14045	17850	28455	31331	17000	600	2573	2808	62073	52589	-18
	8	19.82	30	4	"	"	"	"	"	"	2058	2863	61558	52644	-17
	8	10.87	90	4	"	"	"	"	"	"	0	3445	59500	50126	-19
	5	29.5	0	6	5205	6630	11115	12238	9792	20800	4116	5286	30228	44954	33
AF 58 STORES SHIP	5	28.7	30	6	"	"	"	"	"	"	3430	6004	29542	45672	35
	5	23.98	90	6	"	"	"	"	"	"	0	1677	26112	41344	37
	10	10.0	0	0	19824	61031	35976	39612	0	0	1322	1672	57122	102315	44
	8	21.5	0	4	12625	39719	23025	25352	14260	1500	3965	7727	53875	74298	27
	8	19.82	30	4	"	"	"	"	"	"	2203	7421	52113	73992	30
CA 139 HEAVY CRUISER	8	10.87	90	4	"	"	"	"	"	"	0	1580	49910	68151	27
	5	29.5	0	6	1856	16081	8994	9903	6510	41000	7489	14548	24849	81532	70
	5	28.7	30	6	"	"	"	"	"	"	4846	15560	22206	82544	73
	5	23.98	90	6	"	"	"	"	"	"	0	7690	17360	74674	77
	10	10.0	0	0	72529	59848	109966	121079	0	0	4500	1594	186995	182521	-2
	8	21.5	0	4	47708	30058	70377	77490	47234	1300	6750	7368	172069	116216	-48
	8	19.82	30	4	"	"	"	"	"	"	5400	7514	170719	116362	-47
	8	10.87	90	4	"	"	"	"	"	"	0	904	165319	109752	-50
	5	29.5	0	6	17596	15566	27491	30270	27052	32500	10800	13871	82939	92207	10
	5	28.7	30	6	"	"	"	"	"	"	9000	15755	81139	94091	14
	5	23.98	90	6	"	"	"	"	"	"	0	4399	72139	82735	13

Table 8-1 (Cont'd) CORRELATION STUDY COMPARING THE RESULTS FROM MR&S METHOD WITH THE CURRENT U.S. NAVY TOWING MANUAL

SHIP CLASS	TOW SPEED KT.	REL. WIND SPEED KT.	REL. WIND DIRECTION & DEG.	BEAU-FORT NO.	HULL RESISTANCE LB.		PROPELLER RESISTANCE LB.		SEA STATE RESISTANCE LB.		WIND RESISTANCE LB.		TOTAL RESISTANCE LB.		% DIFF. TOT. RESIS LB.
					USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	USN	MR&S	
LST-1179 TANK LANDING SHIP	10	10.0	0	0	45883	32951	36703	40412	0	0	1970	1396	84556	74759	-13%
	8	21.5	0	4	29065	22002	23490	25864	21021	1300	5122	6451	78698	55617	-41
	8	19.82	30	4	"	"	"	"	"	"	3940	6579	81918	55745	-47
	8	10.87	90	4	"	"	"	"	"	"	0	791	73576	49957	-47
	5	29.5	0	6	11679	9064	9176	10103	12513	38500	9850	12145	43218	69812	38
CGN-25 GUIDED MISSILE FRIGATE	5	28.7	30	6	"	"	"	"	"	"	7880	13794	41248	71461	42
	5	23.98	90	6	"	"	"	"	"	"	0	3852	33368	61519	45
	10	10.0	0	0	96368	50944	80981	89165	0	0	1520	1077	178869	141186	-27
	8	21.5	0	4	55422	32497	51828	57065	42900	500	3648	4977	153798	95039	-62
	8	19.82	30	4	"	"	"	"	"	"	3040	5076	153190	95138	-61
	8	10.87	90	4	"	"	"	"	"	"	0	611	150150	90673	-66
	5	29.5	0	6	20939	13299	20245	22291	24711	18650	7904	9371	73799	63611	-16
	5	28.7	30	6	"	"	"	"	"	"	6080	10643	71975	64883	-11
	5	23.98	90	6	"	"	"	"	"	"	0	2972	65895	57212	-15

values for a zero Beaufort number since the values for propeller resistance are within eleven per cent of each other. The differences in hull resistance result from a small data base used in the U.S. Navy towing manual. Only five resistance curves exist to apply to all ship classes whereas the MR&S method has 39 resistance curves. The biggest differences occur with ships like the ATF-148 or the AOE-1 which do not seem to fit any of the five ship classifications used in the towing manual.

The MR&S calculation for propeller resistance always yields value eleven per cent higher than the method from the towing manual since the equation for propeller resistance is the same but the MR&S coefficient is eleven per cent greater than that from the towing manual. One difference between the two methods which is not evident in the correlation study is that in the MR&S method, propeller resistance is separate from hull resistance so it is not a function of ship displacement. Thus the total propeller projected area, which can vary greatly even among similar ships, is accurately accounted for.

There is very poor correlation between the two methods of calculation for sea state resistance. The reason for the discrepancy is that in the Navy method the sea state factor K_1 is a percentage of the calm water resistance which is not correct as demonstrated by Marou's work (Ref.27). The K_1 factor is also multiplied by the propeller resistance which should not be involved in the correction for sea state. The MR&S method presents nine curves for the added resistance in waves which is added to the calm water resistance. Only one ship speed was used for each curve but this is considered a reasonable simplification since added resistance in waves

does not vary greatly over the speed range considered. Note that the added resistance in waves decreased greatly as the Beaufort number increased from 4 to 6 in the Navy calculation. This is a result of the reduction in speed which causes a significant change in calm water resistance. If the Beaufort remained the same, as ship speed decreased the actual added resistance would probably increase for low significant wave heights but the method in the towing manual would indicate a substantial decrease in added resistance. The MR&S calculation for added resistance in waves appears to yield more consistent results.

The results of the MR&S calculation for wind resistance are always greater than those of the towing manual, in some cases by a factor of three. Since documentation for the development of the calculation procedure in the towing manual was not available, it is not possible to fully explain this discrepancy. Use of the K factor in the MR&S method produces a longitudinal force with a beam wind while the method in the towing manual always produces a force of zero for a beam wind. The difference in wind resistance generally amounts to less than eight per cent of the total resistance. When more wind tunnel data becomes available it may be possible to reduce the factors of safety used in the present calculation.

All of the differences of the individual resistance components above

combine together to produce the differences in total tow resistance.

The per cent difference ranges from 2% to 77%.

8.2.2 Part 11-Comparison of Calculation Procedures with Full Scale Tests

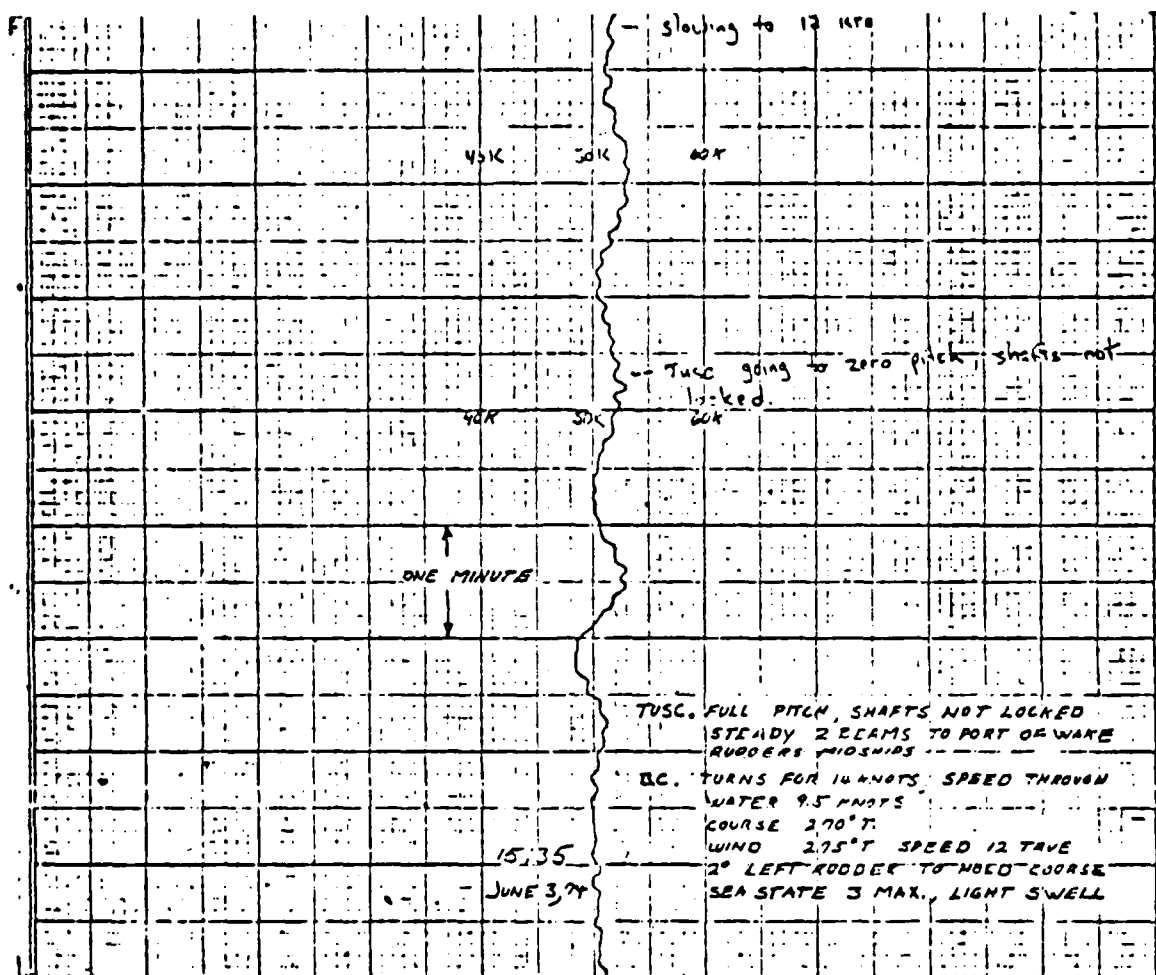
Results were obtained from full scale towing tests of the LST 1179 class for several tow conditions (Ref. 28). Two straight line towing tests were used since direct correlation could be made between these tests and the results of the calculation procedures. The shaft was not locked during the test runs but observers on board the tow noted the shafts never rotated due to the friction of the shafting and gears. Thus the calculations for locked propeller drag are valid. Figures 8-1 and 8-2 provide the data obtained during tests number 1 and 2 respectively. Table 8-2 summarizes the results.

Table 8-2. Summary of Results for Tests #1 & #2 of LST 1179 Class

Test No.	Tow Speed KT.	Rel. Wind Speed KT.	Rel. Wind Dir. Deg.	Measured Tow Resis. Lb. LST 1187 Test (Average)	MR&S Calc. Tow Resis.		U.S.N. Calc. Tow Resis.	
					LB.	% Diff.	LB.	% Diff.
1	9.5	21.48	3	51,000	74234	45	108946	114
2	9	1.44	175	48,000	60990	27	92263	92.2

TEST #1

TOWING AT HIGH SPEED, STRAIGHT COURSE



B.C. TURNS FOR 14 KNOTS
PIT LOG - 9.5 KNOTS
6-ENGINES
COURSE 270° T
WIND 275° T SPEED 12 KNOTS TRUE
2° LEFT RUDDER TO HOLD COURSE
SEA STATE 3 MAX, LIGHT SWELL

TUSC. FULL PITCH, SHAFTS NOT LOCKED
STEADY 2 BEAMS TO PORT OF WAKE
RUDDERS 0 DEGREES

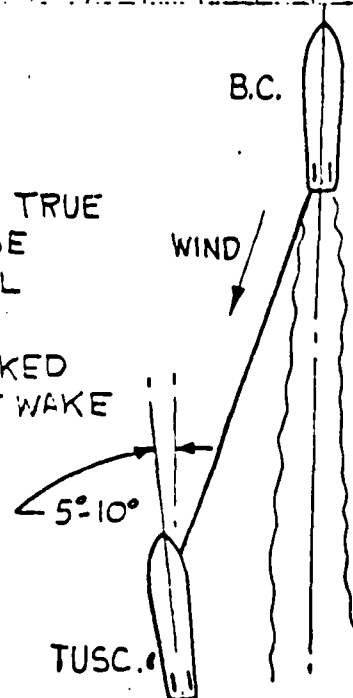
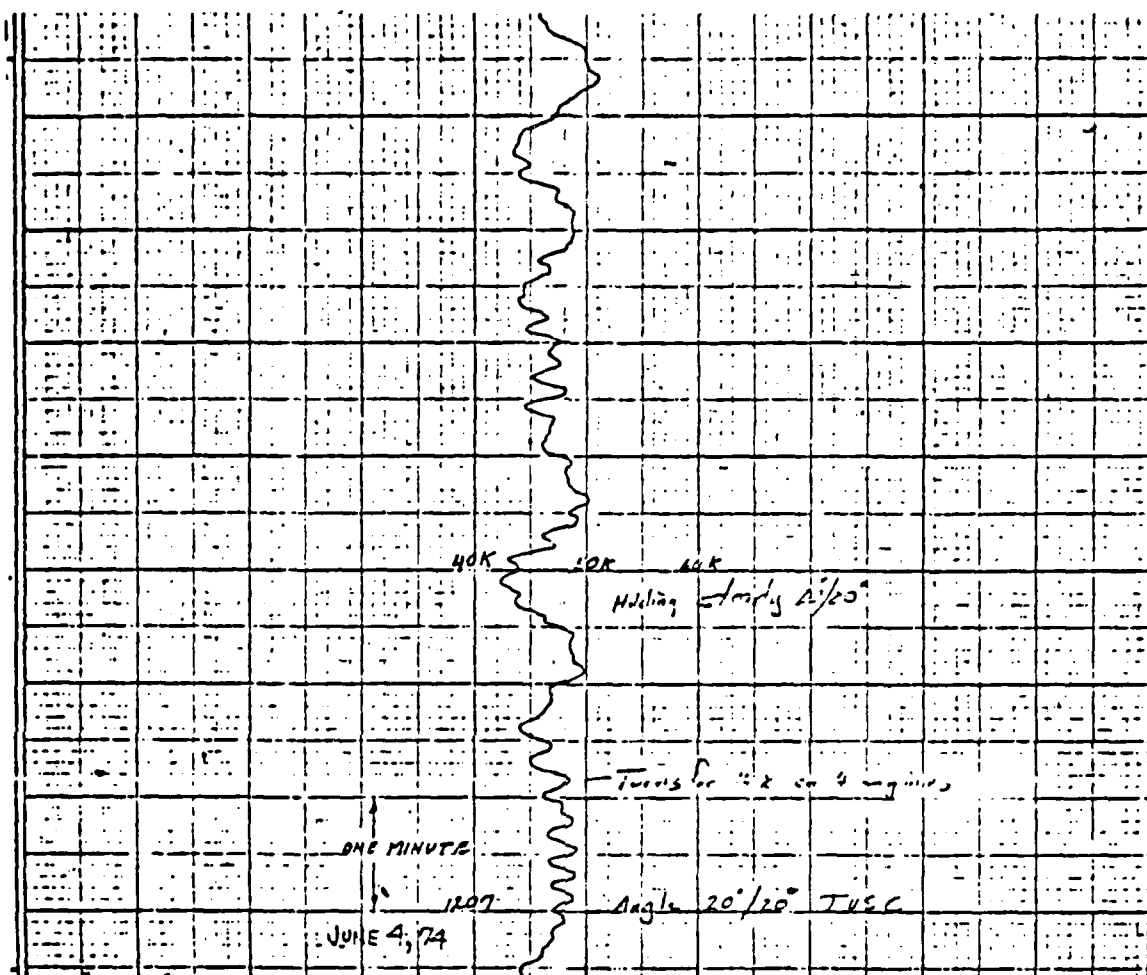


FIGURE 8-1 (Ref. 28)

TEST #2

TURNS FOR 14 KNOTS DOWN WIND



B.C. TURNS FOR 14 KNOTS
 PIT LOG 9 KNOTS
 4 ENGINES
 COURSE 070°T
 WIND 254°T SPEED 10 KNOTS TRUE
 SEA STATE 3 MAX LIGHT SWELL
 RUDDER 4° LEFT TO HOLD COURSE

TUSC FULL PITCH, SHAFTS NOT LOCKED
 RUDDERS 0 DEGREES

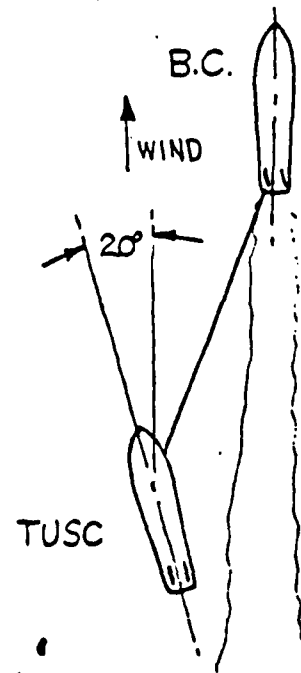


FIGURE 8-2 (Ref. 28)

9. Conclusions

This study has examined the four basic components of tow resistance, hull, propeller, wind and sea state and has combined these components into a calculation procedure for tow resistance. As described in section 2, other factors such as yaw and surge may exist which are not considered in the proposed calculation procedure. These additional factors could significantly increase the tow resistance and should be considered in future studies. No factor of safety has been applied to the final tow resistance since the individual resistance components all have a conservative margin built into them.

The calculation procedure for tow resistance developed in this study is somewhat more complex than the procedure in the present towing manual (Ref. 8) but has the advantages of being more rigorous and fully documented. The biggest difference between the two methods is that calm water hull resistance is considered separately from the propeller resistance unlike the present towing manual which presents the two resistance components together as one curve. The disadvantage of combining hull and propeller resistance on one plot of resistance divided by ship displacement versus speed is that propeller resistance appears to vary with displacement which is not true. With the components combined, it is not possible to disregard the propeller resistance if a ship is towed without propellers. The calculation for propeller resistance derived in this study is quite similar to that used in the Navy towing manual except that the propeller coefficient was increased slightly on the basis of available model tests. The calculation for wind resistance developed in this study is based on the procedure used in powering prediction of U.S. Naval ships (Reference 14) with a few modifications. The advantage

of this method over that used in the current towing manual is that it more rigorously accounts for the effect of heading angle relative to the wind. The sea state factor K_1 as used in the towing manual was eliminated and was replaced by a set of curves of added resistance in waves versus Beaufort number and significant wave height. These curves of added resistance are independent of the propeller resistance and of the calm water resistance. This change should result in more realistic results than were obtained from the calculation procedure currently in use.

The correlation study indicates that significant differences exist between the results obtained from the calculation procedure developed in this report and the U.S. Navy Towing Manual currently in use. The available full scale tow resistance data is too limited to draw final conclusions, but the data obtained thus far indicates that the MR&S calculation procedure yields conservative but more accurate results than the method used in the current U.S. Navy Towing Manual. As additional full scale results become available, it should be possible to make the present calculation procedure less conservative.

10. Recommendations

The calculation procedure for the determination of tow resistance shown in section 7 was developed within the limited scope of the subject task. Further research and development can be undertaken to improve the accuracy of this calculation and extend its applicability. The following recommendations will vary in feasibility and cost.

10.1 Full Scale Tow Resistance Tests

Full scale tow resistance tests are the most effective means of checking the accuracy of the proposed calculation procedure. Full scale tests in calm water would yield valuable information on the magnitude of locked propeller drag since small scale tank tests lose some accuracy due to scaling effects. Tests should be conducted in a range of weather conditions and relative wind headings to determine the accuracy of assumptions made in the calculations for wind resistance and added resistance in waves.

10.2 Inclusion of Additional Parameters

Additional parameters as discussed in section 2 could be included in an extended study. The problem of calculating tow resistance should be considered as a three dimensional rather than two dimensional problem so all six degrees of motion are considered. The increase of resistance while turning is another significant parameter to consider.

10.3 Work on Existing Parameters

Additional research could be conducted on the parameters examined in this study. More hull resistance curves could be added to more accurately define the hull resistance of the naval fleet. In particular, curves for

barges and submarines could be included. The problem of submarine resistance is particularly difficult since submarines are directionally unstable and show a great tendency to yaw while being towed.

The method for determining added resistance in waves used in this study is approximate and can be improved by calculating curves for more ship classes for a range of tow speeds. Instead of assuming a series 60 hull form, computer programs can be used to calculate added resistance for the specific hull shapes considered and in particular would consider transome stern ships. More accurate results would be possible if a two parameter study including wave period as well as significant wave height were used.

The wind resistance is a small component of the total resistance, generally less than 12 percent. However, additional work could be performed to increase the accuracy of this calculation. The most important improvement would be to calculate for a number of ships the additional drag due to yaw which is a function of the relative wind angle and immersed lateral area. Presently this additional drag is assumed to be fifty percent of the wind resistance for all relative wind angles and is based on very limited data.

10.4 Digital Simulations

The most elegant solution to the tow resistance problem would utilize simulation studies based on data from captive model tests. Work has already been done in this area as described in reference 29 where a Continuous System Modeling Program (CSMP) was used to study a tow trajectory versus time.

Using this approach towline forces could be determined for the actual motion of the tow (including yaw and sway motions) which is not considered in the simplified model used in this study. To be effective this would have to be performed for a large number of ships in varying sea conditions which would be quite costly.

11.

References

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APPENDIX A

HULL RESISTANCE CALCULATIONS

AD-A150 941

DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE
DETERMINATION OF TOM RESISTANCE (UNABRIDGED REPORT)(U)
ROSENBLATT (M) AND SON INC NEW YORK APR 76

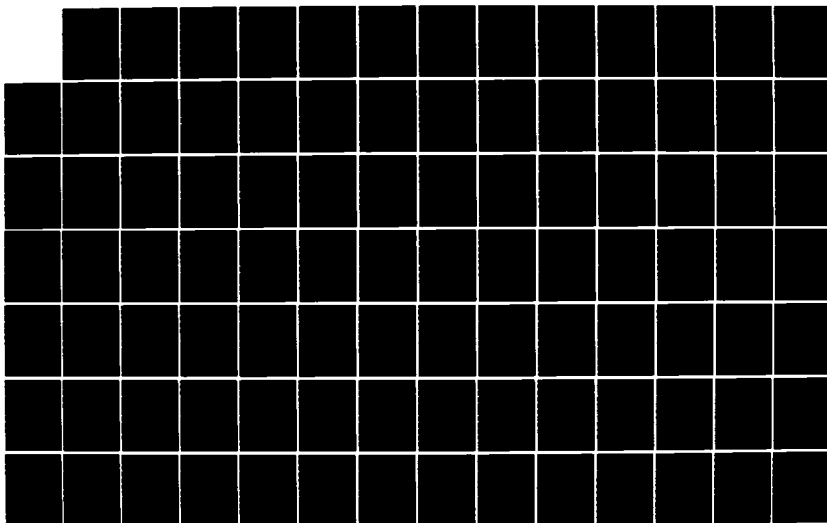
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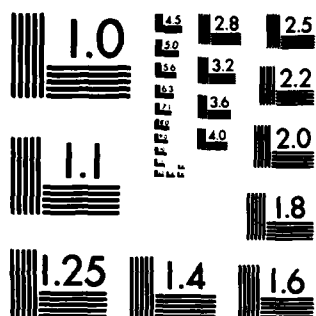
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Appendix A

A.1 Introduction

Appendix A contains the calculations performed for the calm water hull resistance of 39 Naval ship classes. Figures 6-13 show the results of these calculations as they appear in section 7. The list of ship classes below relates the ship classes to the hull resistance curve numbers and gives the sheet number on which the detailed calculations are given in the unabridged report. The unabridged report also provides resistance data for barges. The abridged report presents only a sample calculation for one ship.

A description of the calculation procedure along with a list of symbols used is presented below. Note the change in nomenclature from that used in section 7.

A.2 List of Ships Corresponding to the Hull Resistance Curves

Hull Resistance Curve Numbers (See Fig. 6-13)	Naval Ship Class	Sheet number for Detailed Calculations in Unabridged Report
1	FF-1037	1
2	FF-1040	4
3	DD-931	7
4	CG-16	11
5	CGN-25	14
6	CGN-9	17
7	CA-139	20
8	MSO-422	23
9	ATF-148	26
10	AGFF-1	29
11	T-AGS-29	32
12	AF-58	35
13	AE21 & 23	38
14	AD-14	41

A.2 List of Ships Corresponding to the Hull Resistance Curves (Continued)

Hull Resistance Curve Numbers (See Fig. 6-13)	Naval Ship Class	Sheet number for Detailed Calculations in Unabridged Report
15	AE-26	44
16	LPD-4	47
17	AFS-1	50
18	LST-1179	53
19	LSD-36	56
20	AOR-1	59
21	AD-37	62
22	AOE-1	65
23	AS-34	68
24	AKA-113	71
25	LHA	74
26	AO-93	77
27	CVA(N)-65	80
28	CVA-59	83
29	LCU-FY	86
30	FF-1052	89
31	DDG-2	93
32	DD-963	96
33	T-AGOR	99
34	CG-26	102
35	DD-710	106
36	D2-1	110
37	LST-1171	113
38	LCC-19	116
39	LPH-3	118-A

A.3 Description of Steps in Calculation of Hull Resistance

<u>Symbols Used</u>	<u>Units</u>
LWL = load waterline length	Ft.
B = beam	Ft.
T = draft	Ft.
Δ = displacement	Long Tons
WS = wetted surface	Ft. ²
C_p = prismatic coefficient	--
ΔC_F = ship-model correlation allowance	--
R_T = calm water hull resistance	LB.
Note: R_T is equivalent to R_H in section 7.	
V_K = ship speed	knots
V_s = ship speed	Ft./sec.
R_n = Reynolds number	--
C_f = frictional resistance coefficient	--
C_R = residuary resistance	--
C_{TS} = total coefficient resistance coefficient	--
R_F = frictional resistance	LB.
R_R = Residuary resistance	LB.

Steps in Calculation Procedure

1. Record data for EHP.
2. Calculate speed from $V_K = 0.55\sqrt{LWL}$ and check to see that data exists for this speed or lower. If not then use reference 2 to be sure that C_R is constant at the speed for the lowest EHP available.
3. Calculate the total resistance for the lowest EHP available.
4. Calculate R_n for speed corresponding to this lowest EHP.
5. If the wetted surface is not provided then it may be approximated with the equation

$$S = C_s \sqrt{\nabla \cdot LWL}$$

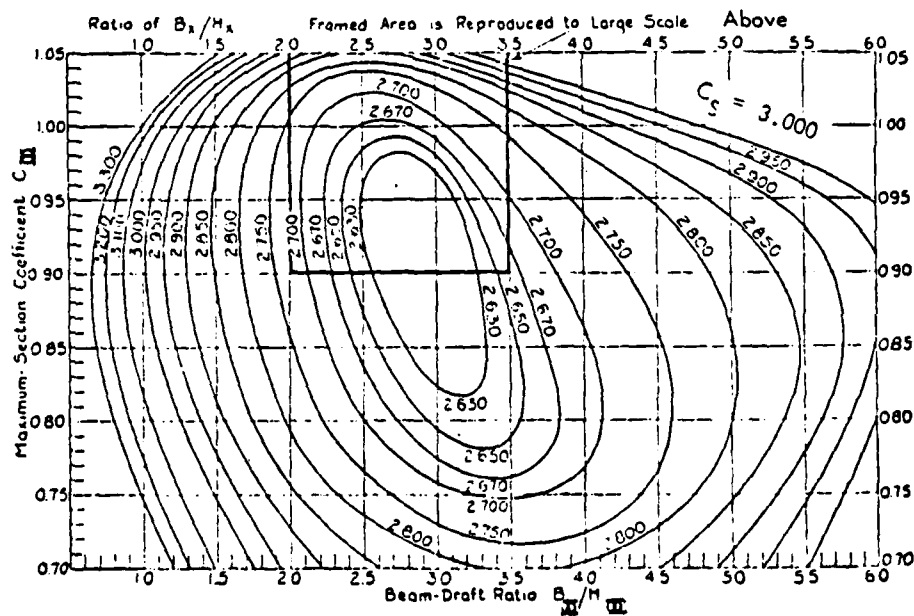
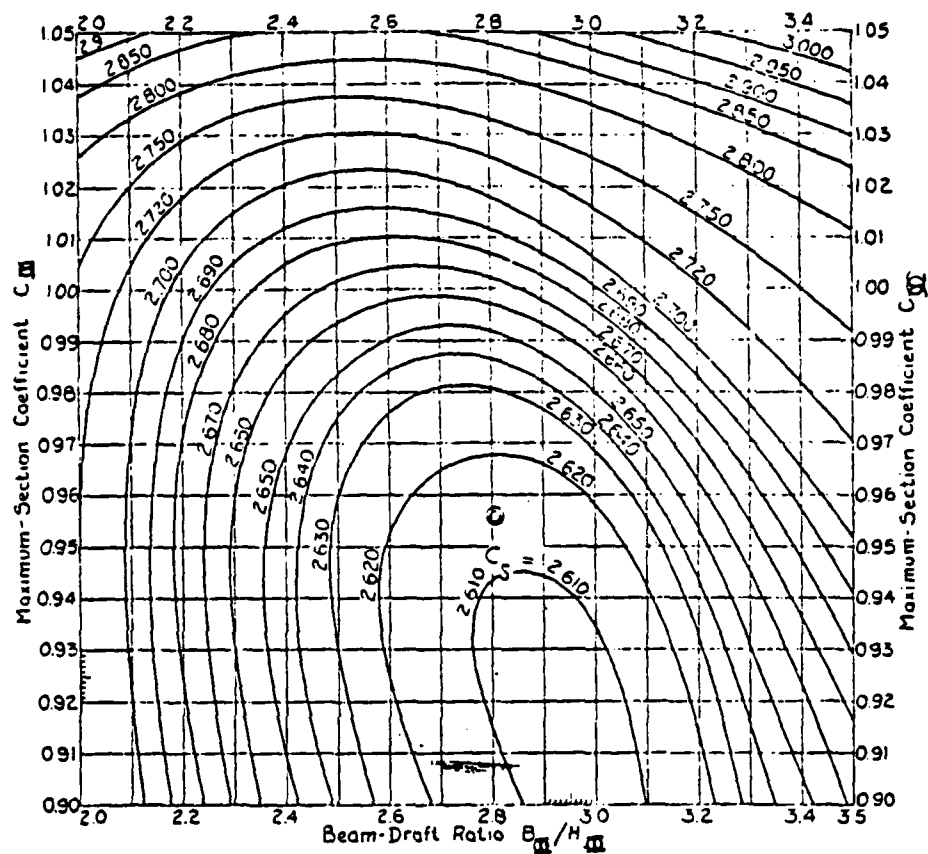
where C_s is obtained from the contours of the non-dimensional wetted surface coefficient (see p. A-6)

∇ = volumetric displacement in cubic feet.

6. Calculate the frictional coefficient using Schoenherr coefficients
7. Calculate frictional resistance.
8. Subtract frictional resistance from total resistance to obtain residuary resistance.
9. Calculate the residuary coefficient which is assumed constant for lower speeds.
10. Calculate Reynold's numbers for speeds from 0-12 knots or from 0 - speed corresponding to lowest EHP.
11. For Reynold's numbers in 9 find C_F using Schoenherr data.
12. Add ΔC_F and C_R to C_F to obtain C_{TS} .
13. Calculate total hull resistance R_H for all towing speeds.
14. Divide R_H by Δ and plot on curves of R_H/Δ versus ship speed V_K .

For more information regarding the above calculation or for the use

of the barge resistance data, consult reference 6 or any standard text on naval architecture.



CONTOURS OF NON-DIMENSIONAL WETTED SURFACE COEFFICIENT
(REFERENCE: SAUNDERS, 1957)

Reviewed

DATA SOURCE : _____

DIA. = 12.75
PITCH = 12.64
BLADES = 5
EXP. A. / D.A. = 0.772
EXPANDED AREA = 78.31
DEVELOPED AREA =
PLAN AREA / D.A. =
PROJECTED AREA =
PROPELLERS = 1

[illegible]

DESIGN CALCULATION SHEET

Sheet 2 of 11E

Subject HULL RESISTANCE CALCULATION - SCB-199 (FF1037)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/29/75 Checked Reviewed

SHIP - SCB-199 OR FF1037

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 10.29 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 24450$$

$$V_S = 1.687 V_K = 16.89$$

$$R_n = \frac{V_S L}{V} = \frac{(16.89)(350)}{1.2791 \times 10^{-5}} = 4.622 \times 10^8$$

$$C_f = 1.687 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.90 \times 10^{-3}$$

$$C_{fT} = 2.587 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (17,440) (16.89)^2 (2.587 \times 10^{-3}) \\ &= 12810 \end{aligned}$$

$$R_R = R_T - R_F = 11640$$

$$C_R = \frac{(11640)}{\frac{1}{2} \rho (17,440) (16.89)^2}$$

$$C_R = 2.351 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{10 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 3 of 13

Subject HULL RESISTANCE CALCULATION - SCB-199 (FF 1037)Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDO

Prepared by

RCSDate 10/29/75 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (350)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.687	0.4622	2.135	0.9	2.351	5.386	267	0.097
2	3.378	0.9244	2.095	"	"	5.346	1059	0.389
3	5.067	1.387	1.980	"	"	5.231	2331	0.855
4	6.756	1.848	1.904	"	"	5.155	4084	1.499
5	8.445	2.311	1.847	"	"	5.098	6311	2.316
6	10.134	2.773	1.803	"	"	5.054	9009	3.306
7	11.823	3.235	1.766	"	"	5.017	12172	4.467
8	13.512	3.698	1.736	"	"	4.987	15804	5.80
9	15.201	4.160	1.710	"	"	4.961	19897	7.302
10	16.89						24450	8.972
11	18.579						29636	10.876
12	20.268						66558	BAD DATA
13	21.957						46392	17.02

DESIGN CALCULATION SHEET

Sheet 5 of 118

Subject HULL RESISTANCE CALCULATION - DE 1040 (FF 1040)Project EMERGENCY TOWING GEAR CRITERIASection BSDD Prepared by RCSDate 10/29/75 Checked

Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 10.86 \quad \underline{\text{USE 7 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 9314$$

$$V_S = 1.687 V_K = 11.823$$

$$R_n = \frac{V_S L}{\nu} = \frac{(11.823)(390)}{1.2791 \times 10^{-5}} = 3.604 \times 10^8$$

$$C_f = 1.742 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\text{Assume } C_x = 0.97$$

$$\Delta C_f = \frac{0.6 \times 10^{-3}}{C_f}$$

$$B_x/H_x = 3.157 \quad C_s = 2.66$$

$$C_{fT} = 2.342 \times 10^{-3}$$

$$S = C_s \sqrt{\nabla \cdot LWL} = 2.66 \sqrt{109585 \cdot 390} = 17,390$$

$$R_F = \frac{1}{2} \rho S V_S^2 C_{fT} = \frac{1}{2} (1.9905) (17,390)^2 (2.342 \times 10^{-3}) = 5666$$

$$R_R = R_T - R_F = 3648$$

$$C_R = \frac{(3648)}{\frac{1}{2} \rho (17,390)^2 (11.823)^2}$$

$$C_R = 1.508$$

CONSTANT C_R FOR SHIP SPEEDS
LESS THAN 7 KT.

DESIGN CALCULATION SHEET

Sheet 6 of 11

Subject HULL RESISTANCE CALCULATION - DE 1040 (FF 1040)Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDD

Prepared by

Date

Checked

Reviewed

SHIP - DE 1040 (FF 1040)

$$R_{hs} = \frac{V_s L}{V} = \frac{V_s (390)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	0.515	2.279	0.6	1.508	4.387	217	0.069
2	3.378	1.030	2.063	"	"	4.171	824	0.263
3	5.067	1.545	1.951	"	"	4.059	1804	0.576
4	6.756	2.060	1.871	"	"	3.979	3143	1.004
5	8.445	2.575	1.821	"	"	3.929	4850	1.549
6	10.134	3.09	1.778	"	"	3.886	6907	2.206
7	11.823						9314	2.975
8	13.512						10188	3.254
9	15.201						14489	4.627
10	16.89						22820	7.288
11	18.579							
12	20.268						40750	13.015
13	21.957							

Sheet 7 of 118

Ship or Project EMERGENCY TOWING GFR CRITERIA

Section BSDD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: DD931

DATA SOURCE : Ref. 1.

PROPELLER CHARACTERISTICS

LWL = 407

$$B = \underline{44.4}$$
$$T = 14.52$$
$$\Delta = \underline{3890}$$
$$WS = \underline{20,600}$$
$$C_p = \underline{\hspace{10cm}}$$
$$ENP/SHP =$$
$$\Delta C_F = \underline{0.001141}$$
$$D_{IA} = 13.25'$$

PITCH = 13.84

* BLADES = 4

EXP. A. / D.A. = _____

EXPANDED AREA = _____

DEVELOPED AREA = _____

$$\text{PROJ. AREA} / D.A = 0.706$$

PROJECTED AREA = 97.37

PROPELLERS = 2

9.11.15

[illegible]

DESIGN CALCULATION SHEET

Sheet 5 of 11A

Subject HULL RESISTANCE CALCULATION - DD 931

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by

RCS

Date 10/28/75 Checked

Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 11.09 \text{ KT, USE EXTRAPOLATED EHP DATA FOR 11 KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 25191$$

$$V_S = 1.687 \quad V_K = 18.579$$

$$R_n = \frac{V_S L}{D} = \frac{(18.579)(407)}{1.2791 \times 10^{-5}} = 5.912 \times 10^8$$

$$C_f = 1.635 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{1.141 \times 10^{-3}}{C_{fT} = 2.776 \times 10^{-3}}$$

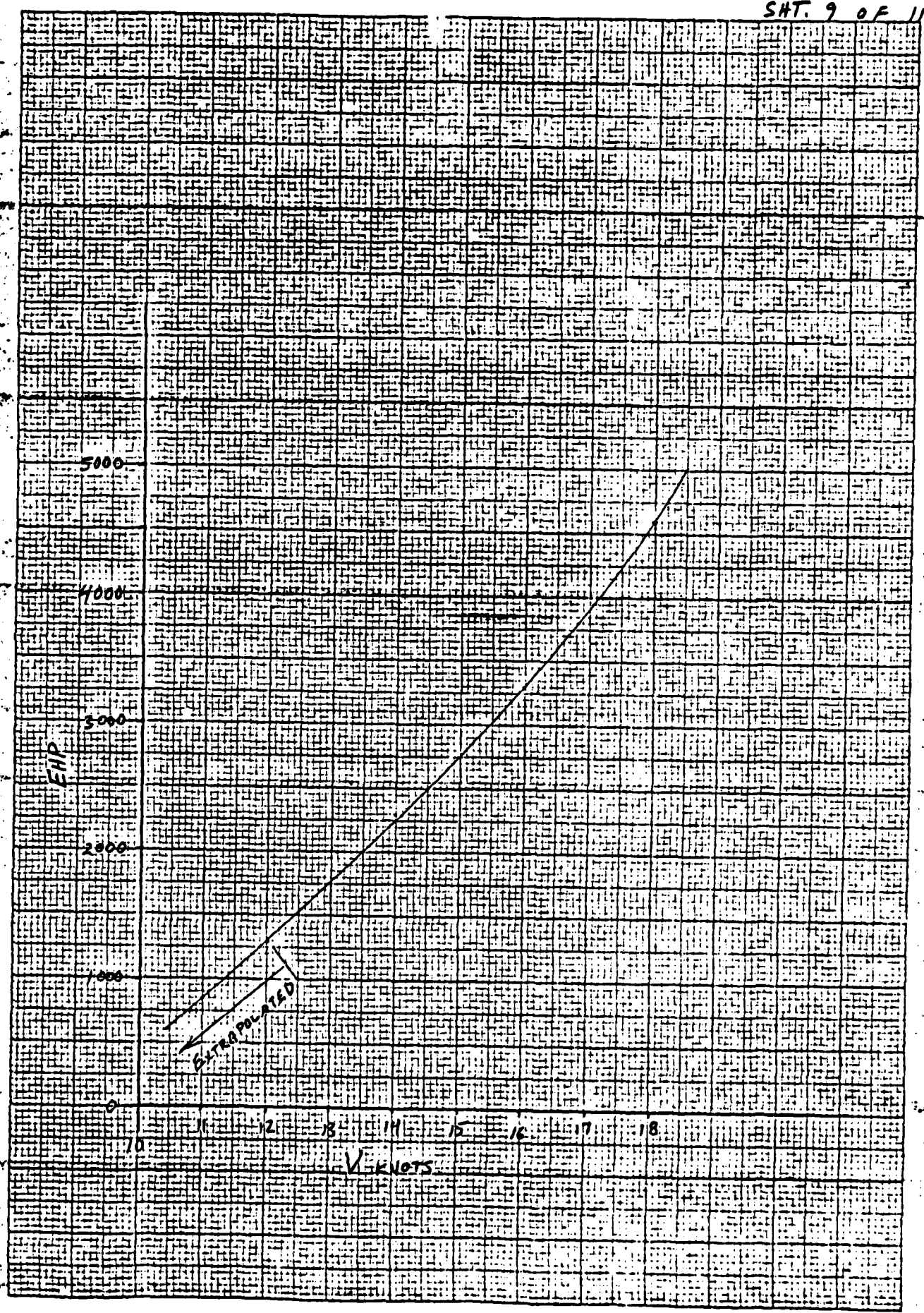
$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (20,600) (18.579)^2 (2.776 \times 10^{-3}) \\ &= 19,646 \end{aligned}$$

$$R_R = R_T - R_F = 5545$$

$$C_R = \frac{(5545)}{\frac{1}{2} \rho (20600) (18.579)^2}$$

$$C_R = 0.784 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{11 \text{ KT.}}$$

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401255



DESIGN CALCULATION SHEET

Sheet 10 of 11

Subject HULL RESISTANCE CALCULATION - DD 931Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/28/75 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (417)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.5374	2.265	1.141	0.784	4.190	245	0.063
2	3.378	1.075	2.051	"	"	3.976	930	0.239
3	5.067	1.612	1.940	"	"	3.865	2034	0.523
4	6.756	2.150	1.865	"	"	3.790	3547	0.919
5	8.445	2.687	1.810	"	"	3.735	5461	1.404
6	10.134	3.224	1.768	"	"	3.693	7776	1.999
7	11.823	3.762	1.734	"	"	3.659	10486	2.696
8	13.512	4.299	1.703	"	"	3.628	13581	3.491
9	15.201	4.837	1.677	"	"	3.602	17064	4.387
10	16.89	5.374	1.655	"	"	3.580	20938	5.383
11	18.579	5.911	1.635	"	"	3.560	25191	6.476
12	20.268	—	—	—	—	—	35317	9.079
13	21.957	—	—	—	—	—	—	—

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project **EMERGENCY TOWING GFR CRITERIA**

Section BSDD

Prepared by **RCS**

Date 12/2/75 Checked

Reviewed

SHIP CLASS: DLG 16

DATA SOURCE : Ref. 1

SHIP CHARACTERISTICS

$$LWL = \underline{\underline{510}}$$

B = 51

$$T = 18$$
$$\Delta = \underline{\underline{6800}}$$

WS = 30980

$$C_p = \underline{\hspace{10cm}}$$
$$EHP'/SHP =$$
$$\Delta C_F = \underline{\underline{0.000955}}$$

PROPELLER CHARACTERISTICS

DIA. = 14.0

Pitch = 13.95

* BLADES = 5

$$\text{EXP. A. / D.A.} = \underline{0.995}$$

EXPANDED AREA = _____

DEVELOPED AREA = _____

PROJ. AREA / D.A. =

PROJECTED AREA = _____

PROPELLERS = 2

[illegible]

DESIGN CALCULATION SHEET

Sheet 12 of 115

Subject HULL RESISTANCE CALCULATION - DLG 16

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date

Checked

Reviewed

SHIP - DLG 16

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.42 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 32600$$

$$V_S = 1.687 V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(510)}{1.2791 \times 10^{-5}} = 6.734 \times 10^8$$

$$C_f = 1.608 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.955 \times 10^{-3}}{C_f}$$

$$C_{fT} = 2.563 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (30980) (16.89)^2 (2.563 \times 10^{-3}) \\ &= 22543 \end{aligned}$$

$$R_R = R_T - R_F = 10057$$

$$C_R = \frac{(10057)}{\frac{1}{2} \rho (30980) (16.89)^2}$$

$$C_R = 1.143$$

CONSTANT C_R FOR SHIP SPEEDS
LESS THAN 10 KT.

DESIGN CALCULATION SHEET

No. 3419

Sheet 13 of 118

Subject HULL RESISTANCE CALCULATION - DLG 24 (DLG 16)Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/29/75 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (510)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6734	2.192	0.955	1.143	4.290	377	0.055
2	3.378	1.347	1.987	"	"	4.085	1437	0.211
3	5.067	2.020	1.881	"	"	3.979	3150	0.463
4	6.756	2.694	1.810	"	"	3.908	5500	0.809
5	8.445	3.367	1.757	"	"	3.855	8477	1.247
6	10.134	4.041	1.716	"	"	3.814	12077	1.776
7	11.823	4.714	1.688	"	"	3.781	16296	2.396
8	13.512	5.387	1.654	"	"	3.752	21121	3.106
9	15.201	6.061	1.630	"	"	3.728	26560	3.906
10	16.89	—	—	—	—	—	32600	4.794
11	18.579	—	—	—	—	—	—	—
12	20.268	—	—	—	—	—	54333	7.99
13	21.957	—	—	—	—	—	—	—

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: DLGN-25 (CGN-25)

DATA SOURCE : _____

SHIP CHARACTERISTICS

$$\begin{aligned}LWL &= 540.0 \\B &= 56.66 \\T &= 18.89 \\\Delta &= 7,800 \\WS &= ? \\C_p &= \\EHP/SHP &= \\AC_E &= 0.000872\end{aligned}$$

PROPELLER CHARACTERISTICS

DIA. = 15.0 FT.

PITCH = 15.71 FT.

BLADES = 5

EXP. A. / D.A. =

EXPANDED AREA =

DEVELOPED AREA = 141.6

PROJ. AREA / D.A. = 119.3

PROJECTED AREA =

PROPELLERS = 2

[illegible]

DESIGN CALCULATION SHEET

Sheet 15 of 118

Subject HULL RESISTANCE CALCULATION - DLGN-25 (CGN-25)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/30/75

Checked

Reviewed

SHIP - DLGN-25 (CGN-25)

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.78 \quad \text{USE 11 KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 44,455$$

$$V_s = 1.687 V_K = 18.579$$

$$R_n = \frac{V_s L}{V} = \frac{(18.579)(540)}{1.2791 \times 10^{-5}} = 7.844 \times 10^8$$

$$C_f = 1.578 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{0.872 \times 10^{-3}}{C_{ft}} = 2.450 \times 10^{-3}$$

$$C_{ft} = 2.450 \times 10^{-3} \quad \begin{matrix} C_x = 0.97 \text{ ASSUMED} \\ B/H = 2.999 \quad C_s = 2.632 \end{matrix}$$

$$S = C \sqrt{T \cdot LWL} = 2.632 \sqrt{7800(35)(540)} = 31,957$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_s^2 C_{FT} \\ &= \frac{1}{2} (1.9905) (31,957) (18.579)^2 (2.45 \times 10^{-3}) \\ &= 26,897 \end{aligned}$$

$$R_R = R_T - R_F = 17,558$$

$$C_R = \frac{(17,558)}{\frac{1}{2} \rho (31,957) (18.579)^2}$$

$$C_R = 1.599 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN 11 KT.}$$

Subject HULL RESISTANCE CALCULATION - DLGN-25 (CGN-25)Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDOPrepared by PCSDate 10/30/75 Checked

Reviewed

SHIP - DLGN-25 (CGN-25)

$$R_{hs} = \frac{V_s L}{\gamma} = \frac{V_s (5400)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	0.7130	2.174	0.872	1.599	4.645	421	0.054
2	3.378	1.426	1.972	"	"	4.443	1612	0.207
3	5.067	2.139	1.866	"	"	4.337	3542	0.454
4	6.756	2.852	1.797	"	"	4.268	6196	0.794
5	8.445	3.565	1.744	"	"	4.215	9561	1.226
6	10.134	4.278	1.704	"	"	4.175	13637	1.748
7	11.823	4.991	1.670	"	"	4.141	18410	2.360
8	13.512	5.704	1.642	"	"	4.113	23883	3.062
9	15.201	6.417	1.618	"	"	4.089	30051	3.853
10	16.89	7.130	1.597	"	"	4.068	36910	4.732
11	18.579						44455	5.699
12	20.268						54333	6.966
13	21.957						62692	8.037

Reviewed

DATA SOURCE : Ref. 1

DIA. = 17.0
PITCH = 19.35
BLADES = 4
EXP. A. / D.A. = 0.834
EXPANDED AREA = 189.3
DEVELOPED AREA =
PROJ. AREA / D.A. =
PROJECTED AREA =
PROPELLERS = 2

[illegible]

DESIGN CALCULATION SHEET

No. 5717
Sheet 18 of 118

Subject HULL RESISTANCE CALCULATION - CG(N) 9

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/28/75 Checked

Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 14.47 \text{ KT.} \quad \underline{\text{USE 14 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 93143$$

$$V_S = 1.687 V_K = 23.646$$

$$R_n = \frac{V_S L}{\nu} = \frac{(23.646)(691.8)}{1.2791 \times 10^{-5}} = 1.2789 \times 10^9$$

$$C_f = 1.486 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.78 \times 10^{-3}}{C_{fT}} = 2.266 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (52,600) (23.646)^2 (2.266 \times 10^{-3}) \\ &= 66552 \end{aligned}$$

$$R_R = R_T - R_F = 26591$$

$$C_R = \frac{(26591)}{\frac{1}{2} \rho (52,600) (23.646)^2}$$

$$C_R = 0.908 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{14 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 19 of 118

Subject HULL RESISTANCE CALCULATION - CG(N) 9Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/28/75 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (691.8)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—					0	0
1	1.689	0.9135	2.098	0.78	0.908	3.786	565	0.040
2	3.378	1.827	1.906	"	"	3.594	2147	0.152
3	5.067	2.741	1.806	"	"	3.494	4696	0.334
4	6.756	3.654	1.739	"	"	3.427	8189	0.582
5	8.445	4.568	1.689	"	"	3.377	12608	0.895
6	10.134	5.481	1.651	"	"	3.339	17951	1.275
7	11.823	6.395	1.618	"	"	3.306	24192	1.718
8	13.512	7.309	1.592	"	"	3.280	31350	2.227
9	15.201	8.222	1.568	"	"	3.256	39386	2.797
10	16.89	9.135	1.548	"	"	3.236	48327	3.432
11	18.579	10.049	1.530	"	"	3.218	58150	4.130
12	20.268	10.962	1.514	"	"	3.202	68859	4.891
13	21.957	11.876	1.499	"	"	3.187	80435	5.713

[illegible]

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - CA-139Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - CA-139

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 14.55 \quad \text{USE } 10 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{1300 \times 326}{10} = 42380$$

$$V_S = 1.687 V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(700)}{1.2791 \times 10^{-5}} = 9.243 \times 10^8$$

$$C_f = \text{---} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{?}{0.}$$

$$C_{fT} = \text{---}$$

$$R_F = \frac{1}{2} \rho S V_S^2 C_{fT} = \frac{1}{2} (1.9905) (\quad) (\quad)$$

$$R_F = \frac{EHP \times 326}{10} = \frac{900 \times 326}{10} = 29340$$

$$R_R = R_T - R_F = 13040$$

$$C_R = \frac{(13040)}{\frac{1}{2} \rho (61884) (16.89)^2}$$

$$C_R = 0.742 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } 10 \text{ KT.}$$

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 22 of 118

Subject HULL RESISTANCE CALCULATION - CA-139

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD Prepared by RCS Date 10/24/75 Checked _____ Reviewed _____

SHIP - CA-139

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (700)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	ASSUMED	—	—	0	0
1	1.689	0.9243	2.095	0.40	0.742	3.237	568	0.027
2	3.378	1.849	1.905	"	"	3.047	2140	0.102
3	5.067	2.773	1.803	"	"	2.945	4654	0.222
4	6.756	3.697	1.736	"	"	2.878	8085	0.386
5	8.445	4.622	1.687	"	"	2.829	12418	0.593
6	10.134	5.546	1.648	"	"	2.79	17636	0.842
7	11.823	6.470	1.616	"	"	2.758	23729	1.133
8	13.512	7.395	1.589	"	"	2.731	30690	1.465
9	15.201	8.319	1.566	"	"	2.708	38514	1.838
10	16.89	—	—	—	—	—	42380	2.023
11	18.579	—	—	—	—	—	—	—
12	20.268	—	—	—	—	—	67917	3.242
13	21.957	—	—	—	—	—	—	—

DESIGN CALCULATION SHEET

No. 3414

Sheet 23 of 115

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GFR CRITERIA

Section BSDD

Prepared by

Date

Checked

Reviewed

SHIP CLASS: M50 422

DATA SOURCE: AM 421 FILE JULY 28, 1950 TEST

SHIP CHARACTERISTICS

LWL = 165.2
B = 34.6
T = 10.5
 Δ = 880
WS = 6230
 C_p =
EHP/SHP =
 ΔC_f = 0.0004

PROPELLER CHARACTERISTICS

DIA. = 6.50'
PITCH = 6.0'
BLADES = 4
EXP. A. / D.A. =
EXPANDED AREA =
DEVELOPED AREA =
PROJ. AREA / D.A. = 0.607
PROJECTED AREA =
PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R _T POUNDS	EHP ERIC. SCHMIDTKE FORMULA
5			22		15
6			38		26
7			60		42
8			92		62
9			138		91
10			205(?)		120 ?
11			297		162
12			433		208
13			620		262

DESIGN CALCULATION SHEET

No. 3414

Sheet 24 of 118

Subject HULL RESISTANCE CALCULATION - MSO 422Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - MSO 422

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{L_{WL}} = 12.85 \text{ USE 5 KT.}$$

$$R_T = \frac{ENP \times 326}{V_K} = 1434.4$$

$$V_s = 1.687 V_K = 8.445$$

$$R_n = \frac{V_s L}{D} = \frac{(8.445)(165.2)}{1.2791 \times 10^{-5}} = 1.091 \times 10^8$$

$$C_f = 2.047 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.4 \times 10^{-3}$$

$$C_{fT} = 2.447 \times 10^{-3}$$

USE THIS $\rightarrow C_{fT} = 2.212 \times 10^{-3}$ (CALCULATED FROM ENP FRIC. RESISTANCE)

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_s^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (6230) (8.445)^2 (2.212 \times 10^{-3}) \\ &= 978.15 \end{aligned}$$

$$R_R = R_T - R_F = 456.3$$

$$C_R = \frac{(456.3)}{\frac{1}{2} \rho (6230) (8.445)^2}$$

$$C_R = 1.032 \times 10^{-3} \text{ CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{5 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - MSO 422Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - MSO 422

$$R_{hs} = \frac{V_s L}{\nu} = \frac{V_s (165.2)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.2181	2.595	0.40	1.032	4.027	71.23	0.081
2	3.378	0.4363	2.335	"	"	3.767	266.5	0.303
3	5.067	0.6544	2.201	"	"	3.633	578.3	0.657
4	6.756	0.8726	2.191	"	"	3.623	1025.3	1.165
5	8.445	1.091	—	—	—	—	1434.4	1.63
6	10.134	1.309	—	—	—	—	2065	2.347
7	11.823	1.527	—	—	—	—	2794	3.175
8	13.512	1.745	—	—	—	—	3749	4.260
9	15.201	1.963	—	—	—	—	4999	5.681
10	16.89	2.181	—	—	—	—	6683	7.594
11	18.579	2.400	—	—	—	—	8802	10.002
12	20.268	2.618	—	—	—	—	11263	13.367
13	21.957	2.836	—	—	—	—	15548	17.668

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE & PROPELLER DATA SHEETShip or Project EMERGENCY TOWING GFR CRITERIASection BSDDPrepared by RCSDate 12/5/75 Checked

Reviewed

SHIP CLASS: ATF-148

DATA SOURCE: _____

SHIP CHARACTERISTICS

LWL = 224
 B = 44.9
 T = 15.75
 Δ = 2080
 WS = 10,654
 C_p = 0.566
 EHP/SHP = _____
 ΔC_F = 0.0006

PROPELLER CHARACTERISTICS

DIA. = 13.0'
 PITCH = 13.0'
 # BLADES = 4
 EXP. A. / D.A. = 0.541
 EXPANDED AREA = _____
 DEVELOPED AREA = _____
 PROJ. AREA / D.A. = _____
 PROJECTED AREA = _____
 # PROPELLERS = 1

V KNOTS	SHp	EHP/SHp	EHP	R _T POUNDS	EHP FRIG.
6			90		
7			160		
8			220		
9			310		
10			420		
11			570		
12			750		
13			980		

DESIGN CALCULATION SHEET

No. 5717

Sheet 27 of 118

Subject HULL RESISTANCE CALCULATION - ATF 148Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - AFT - 148

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 8.23 \text{ USE } \underline{6 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{90 \times 326}{6} = 4890$$

$$V_S = 1.687 V_K = 10.134$$

$$R_n = \frac{V_S L}{V} = \frac{(10.134)(224)}{1.2791 \times 10^{-5}} = 1.775 \times 10^8$$

$$C_f = 1.914 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.60 \times 10^{-3}}{C_{fT}}$$

$$C_{fT} = 2.514 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (10,654) (10.134)^2 (2.514 \times 10^{-3}) \\ &= 27381 \end{aligned}$$

$$R_R = R_T - R_F = 2152$$

$$C_R = \frac{(2152)}{\frac{1}{2} \rho (10,654) (10.134)^2}$$

$$C_R = 1.986 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{6 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 28 of 118

Subject HULL RESISTANCE CALCULATION - ATF - 148Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - ATF - 148

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (224)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.2958	2.475	0.60	1.986	5.061	153	0.074
2	3.378	0.5916	2.233	"	"	4.819	523	0.280
3	5.067	0.8873	2.107	"	"	4.693	1278	0.614
4	6.756	1.183	2.025	"	"	4.611	2232	1.073
5	8.445	1.479	1.962	"	"	4.548	3439	1.653
6	10.134	—	—	—	—	—	4896	2.351
7	11.823	—	—	—	—	—	7451	3.582
8	13.512	—	—	—	—	—	8965	4.310
9	15.201	—	—	—	—	—	11229	5.399
10	16.89	—	—	—	—	—	13692	6.583
11	18.579	—	—	—	—	—	16893	8.122
12	20.268	—	—	—	—	—	20375	9.796
13	21.957	—	—	—	—	—	24575	11.815

Reviewed

PROPELLERS = 2

[illegible]

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - AGDE-1 OR AGFF-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by JCSDate 10/22/75 Checked

Reviewed

SHIP - AGDE-1 (AGFF-1)

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{VLWL} = 10.86 \quad \underline{\text{USE 9 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 14489$$

$$V_S = 1.689 V_K = 15.201$$

$$R_n = \frac{V_S L}{V} = \frac{(15.201)(390)}{1.2791 \times 10^{-5}} = 4.635 \times 10^8$$

$$C_f = 1.687 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.6 \times 10^{-3}$$

$$C_{fT} = 2.287 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (20,220) (15.201)^2 (2.287 \times 10^{-3}) \\ &= 10635 \end{aligned}$$

$$R_R = R_T - R_F = 3854$$

$$C_R = \frac{(3854)}{\frac{1}{2} \rho (20,220) (15.201)^2}$$

$$C_R = 0.828 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{9 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - AGDE-1 (AGFF-1)

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/27/75 Checked

Reviewed

SHIP - AGDE-1 (AGFF-1)

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (390)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0							0	0
1	1.689	0.5150	2.279	0.6	0.828	3.207	213	0.061
2	3.378	1.030	2.063	"	"	3.491	802	0.229
3	5.067	1.545	1.951	"	"	3.379	1746	0.499
4	6.756	2.060	1.876	"	"	3.304	3035	0.867
5	8.445	2.575	1.820	"	"	3.248	4662	1.332
6	10.134	3.09	1.778	"	"	3.206	6626	1.893
7	11.823	3.605	1.742	"	"	3.170	8917	2.548
8	13.512	4.120	1.712	"	"	3.14	11537	3.296
9	15.201						14489	4.140
10	16.89						22820	6.52
11	18.579						31118	8.891
12	20.268						39033	10.867
13	21.957						45138	12.897

Reviewed

PROPELLERS = _____

[illegible]

RESISTANCE CALCULATION SHEET

no. 5711
Sheet 33 of 118

Subject HULL RESISTANCE CALCULATION - T-AGS-29

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/29/75 Checked

Reviewed

SHIP - T-AGS-29

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 10.39 \quad \underline{\text{USE 7 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 7777$$

$$V_S = 1.687 V_K = 11.823$$

$$R_n = \frac{V_S L}{\nu} = \frac{(11.823)(357)}{1.2791 \times 10^{-5}} = 3.30 \times 10^8$$

$$C_f = 1.762 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.4 \times 10^{-3}}{C_{ft}} = 2.162 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{ft} \\ &= \frac{1}{2} (1.9905) (19470) (11.823)^2 (2.162 \times 10^{-3}) \\ &= 5856 \end{aligned}$$

$$R_R = R_T - R_F = 1921$$

$$C_R = \frac{(1921)}{\frac{1}{2} \rho (19470) (11.823)^2}$$

$$C_R = 0.709 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{7 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - T-AGS-29Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDNPrepared by RCSDate 10/29/75 Checked

Reviewed

SHIP -

$$R_{hs} = \frac{V_s L}{\gamma} = \frac{V_s (357)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.687	0.4714	2.309	0.4	0.709	3.418	189	0.044
2	3.378	0.9428	2.089	"	"	2.317	512	0.118
3	5.067	1.414	1.974	"	"	2.189	1089	0.252
4	6.756	1.886	1.898	"	"	3.007	2660	0.615
5	8.445	2.357	1.842	"	"	2.951	4078	0.943
6	10.134	2.828	1.798	"	"	2.907	5785	1.338
7	11.823	—	—	—	—	—	7777	1.798
8	13.512	—	—	—	—	—	9943	2.299
9	15.201	—	—	—	—	—	12533	2.898
10	16.89	—	—	—	—	—	15485	3.580
11	18.579	—	—	—	—	—	18819	4.351
12	20.268	—	—	—	—	—	22467	5.195
13	21.957	—	—	—	—	—	26607	6.152

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DESIGN CALCULATION SHEET

No. 3419
Sheet 36 of 118

Subject HULL RESISTANCE CALCULATION - AF 58

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/27/75 Checked

Reviewed

SHIP - AF 58

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.094 \text{ USE } 11 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 41491$$

$$V_s = 1.687 V_K = 18.579$$

$$R_n = \frac{V_s L}{V} = \frac{(18.579)(483.5)}{1.2791 \times 10^{-5}} = 7.023 \times 10^8$$

$$C_f = 1.600 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.77 \times 10^{-3}}{}$$

$$C_{fT} = 2.37 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_s^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (35913) (18.579)^2 (2.37 \times 10^{-3}) \\ &= 29240 \end{aligned}$$

$$R_R = R_T - R_F = 12251$$

$$C_R = \frac{(12251)}{\frac{1}{2} \rho (35913) (18.579)^2}$$

$$C_R = 0.993 \times 10^{-3} \text{ CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } 11 \text{ KT.}$$

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - AF 58Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/27/75 Checked

Reviewed

SHIP - AF 58

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (483.5)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6384	2.209	0.77	0.993	3.972	405	0.037
2	3.378	1.277	2.003	"	"	3.766	1536	0.139
3	5.067	1.915	1.894	"	"	3.657	3356	0.305
4	6.756	2.554	1.823	"	"	3.586	5850	0.532
5	8.445	3.192	1.770	"	"	3.533	9006	0.819
6	10.134	3.831	1.728	"	"	3.491	12811	1.165
7	11.823	4.469	1.694	"	"	3.457	17272	1.570
8	13.512	5.108	1.665	"	"	3.428	22370	2.034
9	15.201	5.746	1.641	"	"	3.404	28114	2.556
10	16.89	6.384	1.619	"	"	3.382	34484	3.135
11	18.579	—	—	—	—	—	41491	3.772
12	20.268	—	—	—	—	—	51617	4.692
13	21.957	—	—	—	—	—	61438	5.585

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by

RCS

Date 12/5/75 Checked

Reviewed

SHIP CLASS: AE 21 & 23

DATA SOURCE : DTMB report No. 923 - TEST 3

SHIP CHARACTERISTICS

LWL = 482'

$$B = \underline{72'}$$
$$T = 29'$$
$$\Delta = \underline{17303}$$

WS = 44606

$C_p =$ _____

$$EHP/SHP =$$
$$\Delta C_F = \underline{0.00077}$$

PROPELLER CHARACTERISTICS

DIA. = 22.0

PITCH = 21.7

* BLADES = 4

EXP. A. / D.A. = _____

EXPANDED AREA = _____

DEVELOPED AREA = _____

$$\text{PROJ. AREA} / \text{D.A.} = 0.431$$

PROJECTED AREA = _____

PROPELLERS = 1

[illegible]

SIGN CALCULATION SHEET

No. 3419

Sheet 39 of 118

Project HULL RESISTANCE CALCULATION - AE 21 & AE 23

Set EMERGENCY TOWING GEAR CRITERIA

Revision BSDD

Prepared by RCS

Date 10/23/75

Checked

Reviewed

SHIP - AE 21 & AE 23

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.07 \text{ KT. USE } 9 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 28616$$

$$V_S = 1.689 V_K = 15.201$$

$$R_n = \frac{V_S L}{\rho} = \frac{(\quad)(\quad)}{1.2791 \times 10^{-5}} = \underline{\hspace{2cm}}$$

$$C_f = \underline{\hspace{2cm}} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \underline{\hspace{2cm}}$$

$$C_{fT} = \underline{\hspace{2cm}}$$

$$R_F = \frac{1}{2} \rho S V_S^2 C_{fT}$$

$$= \frac{1}{2} (1.9905) \cdot (\quad)(\quad)(\quad)$$

$$R_F = \frac{EHP \times 326}{9} = 22096$$

$$R_R = R_T - R_F = 6520$$

$$C_R = \frac{(6520)}{\frac{1}{2} \rho (44606) (15.201)^2}$$

$$C_R = 0.636 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } 9 \text{ KT.}$$

DESIGN CALCULATION SHEET

No. 3419

Sheet 40 of 118

Subject HULL RESISTANCE CALCULATION - AE 21 & AE 23

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/23/75

Checked

Reviewed

SHIP - AE 21 & AE 23

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (482)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	0.6365	2.209	0.4	0.636	3.245	126	0.0073
2	3.378	1.273	2.004	"	"	3.04	1540	0.089
3	5.067	1.909	1.895	"	"	2.931	3341	0.193
4	6.756	2.546	1.822	"	"	2.858	5791	0.335
5	8.445	3.182	1.771	"	"	2.807	8887	0.514
6	10.134	3.819	1.729	"	"	2.765	12606	0.729
7	11.823	4.455	1.695	"	"	2.731	16947	0.979
8	13.512	5.092	1.670	"	"	2.706	21933	1.268
9	15.201						26616	1.654
10	16.89						32252	1.922
11	18.579						40898	2.364
12	20.268						49172	2.842
13	21.957						57175	3.304

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GFR CRITERIA

Section B5DD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: AD-14

DATA SOURCE : AD-19 DATA EXP. # 8

SHIP CHARACTERISTICS

LWL = 531

$$B = \underline{\underline{73}}$$
$$T = 26$$
$$\Delta_{\text{TESTED}} = \underline{\underline{17,000}}$$
$$WS = \underline{48,934}$$

$C_p =$ _____

$$EHP/SHP =$$
$$\Delta C_F =$$

PROPELLER CHARACTERISTICS

Dia. = 15.4

Pitch = 15.4

* BLADES = 3

EXP. A. / D.A. = _____

EXPANDED AREA =

DEVELOPED AREA =

$$\text{PROJ. AREA} / D A = 0.335$$

PROJECTED AREA = 62.4

PROPELLERS = 2

[illegible]

DESIGN CALCULATION SHEET

no. 5111

Sheet 42 of 116

Subject HULL RESISTANCE CALCULATION - AD-14Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - AD-14

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.7 \text{ USE } \underline{8 \text{ KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{650 \times 326}{8} = 26488$$

$$V_s = 1.687 V_K = 13.512$$

$$R_n = \frac{V_s L}{D} = \frac{(13.512)(531)}{1.2791 \times 10^{-5}} = 5.609 \times 10^8$$

$$C_f = 1.646 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_c = \frac{0.40 \times 10^{-3}}{C_{fT}}$$

$$C_{fT} = 2.046 \times 10^{-3}$$

$$\text{USE THIS} \rightarrow C_{fT} = \frac{420 \times 326}{8 \left(\frac{1}{2}\right) \rho (48934) (13.512)^2} = 1.925 \times 10^{-3} \quad (\text{FROM EHP})$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_s^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (48,934) (13.512)^2 (1.925 \times 10^{-3}) \\ &= 17,115 \end{aligned}$$

$$R_R = R_T - R_F = 9373$$

$$C_R = \frac{(9373)}{\frac{1}{2} \rho (48,934) (13.512)^2}$$

$$C_R = 1.054 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{8 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 43 of 118

Subject HULL RESISTANCE CALCULATION - AD-14Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - AD-14

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (531)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7012	2.179	0.400	1.054	3.633	505	0.028
2	3.378	1.402	1.977	"	"	3.431	1907	0.106
3	5.067	2.103	1.871	"	"	3.325	4158	0.231
4	6.756	2.805	1.801	"	"	3.255	7236	0.402
5	8.445	3.506	1.748	"	"	3.202	11,122	0.618
6	10.134	4.207	1.707	"	"	3.161	15,910	0.878
7	11.823	4.908	1.674	"	"	3.128	21,294	1.183
8	13.512	—	—	—	—	—	26,486	1.471
9	15.201	—	—	—	—	—	30,789	1.711
10	16.89	—	—	—	—	—	34,490	2.083
11	18.579	—	—	—	—	—	45,344	2.519
12	20.268	—	—	—	—	—	54,333	3.019
13	21.957	—	—	—	—	—	64,197	3.567

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 44 of 112

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GPR CRITERIA

Section BSDD Prepared by RCS Date 12/5/75 Checked _____ Reviewed _____

SHIP CLASS: AE-26

DATA SOURCE : TEST 4

SHIP CHARACTERISTICS

$$\begin{aligned}LWL &= 540.0 \\B &= 81.0 \\T &= 28.4 \\\Delta &= 20,600 \\WS &= 54,240 \\C_p &= \\EHP/SHP &= \\\Delta C_F &= 0.0005\end{aligned}$$

PROPELLER CHARACTERISTICS

DIA. = 20.0
PITCH = 23.84
BLADES = 4
EXP. A. / D.A. = 0.62
EXPANDED AREA =
~~DEVELOPED~~ AREA =
PROJ. AREA / D.A. =
PROJECTED AREA =
PROPELLERS = 1

[illegible]

Sub: HULL RESISTANCE CALCULATION - AE-26Ship Project EMERGENCY TOWING GEAR CRITERIASection BSDD Prepared by RCS Date 10/23/75 Checked _____ Reviewed _____

SHIP - AE-26

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.781 \text{ USE } 9 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 36222$$

$$V_S = 1.689 \quad V_K = 15.201$$

$$R_n = \frac{V_S L}{V} = \frac{(15.201)(540)}{1.2791 \times 10^{-5}} = 3.126 \times 10^8$$

$$C_f = 1.774 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.50 \times 10^{-3}$$

$$C_{fT} = 2.274 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (54,240) (15.201)^2 (2.274 \times 10^{-3}) \\ &= 28,365 \end{aligned}$$

$$R_R = R_T - R_F = 7857$$

$$C_R = \frac{(7857)}{\frac{1}{2} \rho (54,240) (15.201)^2}$$

$$C_R = 0.630 \times 10^{-3} \text{ CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } 9 \text{ KT.}$$

DESIGN CALCULATION SHEET

Sheet 46 of 112

Subject HULL RESISTANCE CALCULATION - AE-26

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/23/75

Checked

Reviewed

SHIP -

$$R_{hs} = \frac{V_s L}{V} = \frac{V_s (540)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7130	2.174	0.5	0.63	3.304	509	0.025
2	3.378	1.426	1.972	"	"	3.102	1911	0.093
3	5.067	2.139	1.866	"	"	2.996	4152	0.202
4	6.756	2.852	1.797	"	"	2.927	7212	0.350
5	8.445	3.565	1.745	"	"	2.875	11069	0.537
6	10.134	4.278	1.704	"	"	2.834	15711	0.763
7	11.823	4.991	1.670	"	"	2.80	21128	1.026
8	13.512	5.704	1.642	"	"	2.772	27320	1.326
9	15.201	—	—	—	—	—	36222	1.758
10	16.89	—	—	—	—	—	45314	2.20
11	18.579	—	—	—	—	—	53345	2.590
12	20.268	—	—	—	—	—	63842	3.10
13	21.957	—	—	—	—	—	75231	3.652

HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING CRITERIASection BSDD

Prepared by

Date

Checked

Reviewed

SHIP CLASS: LPD 4DATA SOURCE: REF. 1SHIP CHARACTERISTICSLWL = 548.2B = 82.1T = 22.0 Δ = 17,000WS = 51,720 C_p =

EHP/SHP =

 ΔC_F = 0.0005PROPELLER CHARACTERISTICSDIA. = 12.5PITCH = 14.83# BLADES = 5EXP. A. / D.A. = 0.852

EXPANDED AREA =

DEVELOPED AREA = 102

PROJ. AREA / D.A. =

PROJECTED AREA = 87.7# PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R _T POUNDS	EHP ERIG.
8			650		
9			900		
10			1300		
11			1800		
12			2300		
13			2750		
14			3750		

Subject HULL RESISTANCE CALCULATION - LPD 4Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/29/75 Checked

Reviewed

SHIP - LPD 4

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.88 \text{ USE } 8 \text{ KT.}$$

$$R_T = \frac{EHP \cdot 1326}{V_K} = 26488$$

$$V_S = 1.687 V_K = 13.512$$

$$R_n = \frac{V_S L}{V} = \frac{(1352)(548.2)}{1.2771 \times 10^{-5}} = 5.791 \times 10^8$$

$$C_f = 1.639 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.5 \times 10^{-3}}{C_{fT}} = 2.139 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (51,720) (13.512)^2 (2.139 \times 10^{-3}) \\ &= 20,102 \end{aligned}$$

$$R_R = R_T - R_F = 6386$$

$$C_R = \frac{(6386)}{\frac{1}{2} \rho (51,720) (13.512)^2}$$

$$C_R = 0.680 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{8 \text{ KT.}}$$

TUG RESISTANCE CALCULATION - LPD 4

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSD Prepared by RCS Date 10/29/75 Checked _____ Reviewed _____

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (548.2)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./\Delta
0	0						0	0
1	1.689	0.7239	2.170	0.5	0.68	3.35	492	0.029
2	3.378	1.448	1.968	"	"	3.148	1849	0.109
3	5.067	2.172	1.863	"	"	3.043	4022	0.237
4	6.756	2.896	1.792	"	"	2.972	6983	0.411
5	8.445	3.619	1.741	"	"	2.921	10723	0.631
6	10.134	4.343	1.701	"	"	2.881	15230	0.896
7	11.823	5.067	1.667	"	"	2.847	20485	1.205
8	13.512						26488	1.558
9	15.201						32600	1.918
10	16.89						42380	2.493
11	18.579						53345	3.138
12	20.268						62483	3.675
13	21.957						68962	4.056

Section BSDD Prepared by _____ Date _____ Checked _____ Reviewed _____

DATA SOURCE : REF. 1

PROPELLER CHARACTERISTICS

DIA. = 20.0

PITCH = 21.384

* BLADES = 6

EXP. A. / D.A. =

EXPANDED AREA =

DEVELOPED AREA = 256.32

PROJ. AREA / D.A. =

PROJECTED AREA = 216.5

* PROPELLERS = 1

[illegible]

Subject HULL RESISTANCE CALCULATION - AFS-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/27/75 Checked

Reviewed

SHIP-

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{VLWL} = 12.66 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 39120$$

$$V_S = 1.689 \quad V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(530)}{1.2791 \times 10^{-5}} = 6.998 \times 10^8$$

$$C_f = 1.600 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.8 \times 10^{-3}}{C_{fT}}$$

$$C_{fT} = 2.4 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (48,800) (16.89)^2 (2.4 \times 10^{-3}) \\ &= 33252 \end{aligned}$$

$$R_R = R_T - R_F = 5868$$

$$C_R = \frac{(5868)}{\frac{1}{2} \rho (48,800) (16.89)^2}$$

$$C_R = 0.423 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{10 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - AFS-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/27/75 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (530')}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.6998	2.180	0.8	0.423	3.403	472	0.027
2	3.378	1.400	1.977	"	"	3.20	1773	0.101
3	5.067	2.100	1.871	"	"	3.094	3858	0.220
4	6.756	2.799	1.801	"	"	3.024	6704	0.383
5	8.445	3.499	1.749	"	"	2.972	10294	0.588
6	10.134	4.199	1.708	"	"	2.931	14619	0.835
7	11.823	4.899	1.674	"	"	2.897	19668	1.124
8	13.512	5.599	1.646	"	"	2.869	25440	1.454
9	15.201	6.299	1.622	"	"	2.845	31929	1.825
10	16.89	—	—	—	—	—	39120	2.235
11	18.579	—	—	—	—	—	50382	2.879
12	20.268	—	—	—	—	—	61125	3.493
13	21.957	—	—	—	—	—	71469	4.084

[illegible]

Subject HULL RESISTANCE CALCULATION - LST 1179Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDD

Prepared by

Date

Checked

Reviewed

SHIP - LST 1179

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.29 \text{ (USE 12.0 KT.)}$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{1408 \times 326}{12} = 38251$$

$$V_S = 1.689 V_K = 20.268$$

$$R_n = \frac{V_S L}{\nu} = \frac{(20.268)(500)}{1.2791 \times 10^{-5}} = 7.922 \times 10^8$$

$$C_f = 1.576 \times 10^{-3} \text{ (SCHOENHERR COEFF.)}$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.076 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (34360) (20.268)^2 (2.076) \times 10^{-3} \\ &= 29,163 \end{aligned}$$

$$R_R = R_T - R_F = 38251 - 29,163 = 9088$$

$$C_R = \frac{R_R}{\frac{1}{2} \rho (34360) (20.268)^2}$$

$$C_R = 0.647 \times 10^{-3} \text{ CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{12 \text{ KT.}}$$

DESIGN CALCULATION SHEET

No. 5417

Sheet 55 of 118

Subject HULL RESISTANCE CALCULATION - LST 1179

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by

Date

Checked

Reviewed

SHIP- LST 1179

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (500)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.660	2.198	0.5	0.647	3.345	326	0.038
2	3.378	1.320	1.993	"	"	3.14	1225	0.144
3	5.067	1.981	1.886	"	"	3.033	2663	0.313
4	6.756	2.641	1.814	"	"	2.961	4622	0.544
5	8.445	3.301	1.762	"	"	2.909	7095	0.835
6	10.134	3.961	1.721	"	"	2.868	10072	1.185
7	11.823	4.622	1.687	"	"	2.834	13547	1.594
8	13.512	5.282	1.658	"	"	2.805	17513	2.060
9	15.201	5.942	1.634	"	"	2.781	21975	2.585
10	16.89	6.602	1.612	"	"	2.759	26915	3.166
11	18.579	7.263	1.593	"	"	2.74	32343	3.805
12	20.268	7.923	1.576	"	"	2.723	38251	4.500
13	21.957	8.583	—	"	—	—	44135	5.192

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GENR CRITERIA

Section BSDD

Prepared by

Date

Checked

Reviewed

SHIP CLASS: LSI 36

DATA SOURCE : REF. 1

SHIP CHARACTERISTICS

$$\begin{aligned}LWL &= 540.0 \\B &= 32.0 \\T &= 19.11 \\\Delta &= 14,010 \\WS &= 45,190 \\C_p &= \\EHP/SHP &= 0.68 \\\Delta C_F &= 0.0006\end{aligned}$$

PROPELLER CHARACTERISTICS

DIA. = 12.50

PITCH = 11.89

* BLADES = 5

EXP. A. / D.A. =

EXPANDED AREA =

DEVELOPED AREA = 102

PROJ. AREA / D.A. = 0.713

PROJECTED AREA = 87.7

* PROPELLERS = 2

[illegible]

Subject HULL RESISTANCE CALCULATION - LSD 36Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/29/75 Checked

Reviewed

SHIP - LSD 36

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.78 \quad \underline{\text{USE 12 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 55420$$

$$V_S = 1.689 V_K = 20.268$$

$$R_n = \frac{V_S L}{\rho} = \frac{(20.268)(540)}{1.2791 \times 10^{-5}} = 8.557 \times 10^8$$

$$C_f = 1.561 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.6 \times 10^{-3}$$

$$C_{fT} = 2.161 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (45190) (20.268)^2 (2.161 \times 10^{-3}) \\ &= 39,926 \end{aligned}$$

$$R_R = R_T - R_F = 15,494$$

$$C_R = \frac{(15494)}{\frac{1}{2} \rho (45190) (20.268)^2}$$

$$C_R = 0.839 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{12 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - LSD 36Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/29/75 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (540)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	0.713	2.174	0.6	0.839	3.613	464	0.033
2	3.378	1.426	1.972	"	"	3.411	1751	0.125
3	5.067	2.139	1.866	"	"	3.305	3816	0.272
4	6.756	2.852	1.797	"	"	3.236	6643	0.474
5	8.445	3.565	1.744	"	"	3.183	10210	0.729
6	10.134	4.278	1.704	"	"	3.143	14517	1.04
7	11.823	4.991	1.670	"	"	3.109	19546	1.40
8	13.512	5.704	1.642	"	"	3.081	25299	1.81
9	15.201	6.417	1.618	"	"	3.057	31770	2.27
10	16.89	7.130	1.597	"	"	3.036	38953	2.78
11	18.579	7.844	1.578	"	"	3.017	46838	3.34
12	20.268						55420	3.96
13	21.957						66504	4.75

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project *EMERGENCY TOWING GENR CRITERIA*

Section ESDD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: AOR-1

DATA SOURCE : REF. 1

SHIP CHARACTERISTICS

LWL = 640.0'

$$B = 96'$$
$$T = 32.5'$$
$$\Delta = \underline{\underline{36\,700}}$$

WS = 76,690

$C_p =$ _____

$$EHP/SHP =$$
$$\Delta C_F = \underline{\underline{0.0004}}$$

PROPELLER CHARACTERISTICS

DIA. = 20.5'

PITCH = 23.78

* BLADES = 4

$$\text{EXP. A. / D.A.} = \underline{0.486}$$

EXPANDED AREA = _____

DEVELOPED AREA = _____

PROJ. AREA / D.A. =

PROJECTED AREA =

PROPELLERS = 2

[illegible]

DESIGN CALCULATION SHEET

Sheet 60 of 118

Subject HULL RESISTANCE CALCULATION - AOR-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/28/75 Checked

Reviewed

SHIP - AOR-1

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 13.91 \text{ USE } 12 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 91851$$

$$V_S = 1.687 V_K = 20.268$$

$$R_n = \frac{V_S L}{V} = \frac{(20.268)(640.0)}{1.2791 \times 10^{-5}} = 1.0141 \times 10^9$$

$$C_f = 1.528 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.4 \times 10^{-3}$$

$$C_{fT} = 1.928 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (76,690) (20.268)^2 (1.928 \times 10^{-3}) \\ &= 60450. \end{aligned}$$

$$R_R = R_T - R_F = 31400$$

$$C_R = \frac{(31400)}{\frac{1}{2} \rho (76,690) (20.268)^2}$$

$$C_R = 1.001 \times 10^{-3} \text{ CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } 12 \text{ KT.}$$

DESIGN CALCULATION SHEET

Sheet 61 of 113

Subject HULL RESISTANCE CALCULATION - AOR-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDD

Prepared by

RCSDate 10/28/75

Checked

Reviewed

SHIP - AOR-1

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (210.)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.8334	2.126	0.4	1.001	3.527	768	0.021
2	3.378	1.667	1.931	"	"	3.332	2902	0.079
3	5.067	2.500	1.828	"	"	3.229	6328	0.172
4	6.756	3.333	1.760	"	"	3.161	11012	0.300
5	8.445	4.167	1.709	"	"	3.110	16929	0.461
6	10.134	5.000	1.670	"	"	3.071	24072	0.656
7	11.823	5.834	1.638	"	"	3.039	32423	0.883
8	13.512	6.667	1.610	"	"	3.011	41959	1.143
9	15.201	7.500	1.586	"	"	2.987	52681	1.435
10	16.89	8.334	1.566	"	"	2.967	64602	1.760
11	18.579	9.167	1.547	"	"	2.948	77668	2.116
12	20.268	—	—	—	—	—	91851	2.503
13	21.957	—	—	—	—	—	—	—

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE & PROPELLER DATA SHEETShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDD

Prepared by

Date

Checked

Reviewed

SHIP CLASS: AD 37DATA SOURCE: SHEET FOR TAYLOR STD SERIES FROM FILESHIP CHARACTERISTICS

LWL = 660.0
 B = 85.0
 T = 24.0
 Δ = 24235
 WS =
 C_p = 0.654
 EHP/SHP =
 ΔC_F = 0.0004

PROPELLER CHARACTERISTICS

DIA. = 18.00
 PITCH = 16.848
 # BLADES =
 EXP. A./D.A. =
 EXPANDED AREA =
 DEVELOPED AREA =
 PROJ. AREA/D.A. = 0.534
 PROJECTED AREA = 136
 # PROPELLERS = 1

V KNOTS	SHP	EHP/SHP	EHP	R _T POUNDS	EHP _{ERIC.}
12			2552		
13			3292		
14			4152		
15			5145		
16			6259		

Subject HULL RESISTANCE CALCULATION - AD-37Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/24/75 Checked

Reviewed

SHIP - AD-37

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 14.13 \quad \underline{\text{USE 12 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 69329$$

$$V_S = 1.689 V_K = 20.268$$

$$R_n = \frac{V_S L}{V} = \frac{(20.268)(460.0)}{1.2791 \times 10^{-5}} = 10.458 \times 10^8$$

$$C_f = 1.523 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.4 \times 10^{-3}}{C_f}$$

$$C_{fT} = 1.923 \times 10^{-3}$$

$$\frac{B}{T} = 3.54 \quad C_X = \frac{V}{LBT C_P}$$

$$C_S = 2.71 \quad = 0.963$$

$$S = 2.71 \sqrt{848225 \cdot 660} = 64,120 \text{ FT.}^2$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (64,120) (20.268)^2 (1.923 \times 10^{-3}) \\ &= 50419 \# \end{aligned}$$

$$R_R = R_T - R_F = 18910.$$

$$C_R = \frac{(18910)}{\frac{1}{2} \rho (64,120) (20.268)^2}$$

$$C_R = 0.721 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{12 \text{ KT.}}$$

DESIGN CALCULATION SHEET

No. 5417

Sheet 64 of 118

Subject HULL RESISTANCE CALCULATION - AD-37

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/27/75

Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (660)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

 TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.8715	2.112	0.4	0.721	3.233	589	0.024
2	3.378	1.743	1.919	"	"	3.040	2214	0.091
3	5.067	2.615	1.818	"	"	2.939	4815	0.197
4	6.756	3.486	1.751	"	"	2.872	8365	0.345
5	8.445	4.358	1.700	"	"	2.821	12,839	0.530
6	10.134	5.229	1.660	"	"	2.781	18226	0.752
7	11.823	6.105	1.628	"	"	2.749	24522	1.012
8	13.512	6.972	1.601	"	"	2.722	31714	1.309
9	15.201	7.844	1.578	"	"	2.699	39799	1.642
10	16.89	8.715	1.557	"	"	2.678	48752	2.012
11	18.579	9.587	1.539	"	"	2.660	58594	2.418
12	20.268	—	—	—	—	—	69329	2.861
13	21.957	—	—	—	—	—	89433	3.69

BAD DATA

[illegible]

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - AOE-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/27/75 Checked

Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 15.26 \quad \text{USE } 14 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 181629$$

$$V_S = 1.689 V_K = 23.65$$

$$R_n = \frac{V_S L}{\nu} = \frac{(23.65)(770)}{1.2791 \times 10^{-5}} = 1.4237 \times 10^9$$

$$C_f = 1.467 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{0.725 \times 10^{-3}}{1.467 \times 10^{-3}}$$

$$C_{fT} = 2.192 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (103,520) (23.65)^2 (2.192 \times 10^{-3}) \\ &= 126,316 \end{aligned}$$

$$R_R = R_T - R_F = 55312$$

$$C_R = \frac{(55312)}{\frac{1}{2} \rho (103,520) (23.65)^2}$$

$$C_R = 0.955 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } 14 \text{ KT.}$$

DESIGN CALCULATION SHEET

NO. 2711
Sheet 67 of 116

Subject HULL RESISTANCE CALCULATION - AOE-1

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 10/27/75

Checked

Reviewed

SHIP - AOE-1

$$R_{hs} = \frac{V_s L}{\gamma} = \frac{V_s (770)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—					0	0
1	1.689	1.017	2.067	0.725	0.955	3.747	1101	0.021
2	3.378	2.034	1.879	"	"	3.561	4186	0.078
3	5.067	3.050	1.791	"	"	3.463	9160	0.171
4	6.756	4.067	1.715	"	"	3.397	15975	0.298
5	8.445	5.083	1.667	"	"	3.349	24608	0.459
6	10.134	6.100	1.628	"	"	3.310	35022	0.653
7	11.823	7.117	1.597	"	"	3.279	47223	0.881
8	13.512	8.134	1.571	"	"	3.253	61190	1.142
9	15.201	9.151	1.548	"	"	3.230	76876	1.435
10	16.89	10.168	1.528	"	"	3.210	94345	1.760
11	18.579	11.184	1.510	"	"	3.192	113518	2.118
12	20.268	12.201	1.494	"	"	3.176	134418	2.508
13	21.957	13.218	1.480	"	"	3.162	157060	2.93

DESIGN CALCULATION SHEET

Sheet 69 of 118

Subject HULL RESISTANCE CALCULATION - AS 33Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/29/75 Checked

Reviewed

SHIP - AS 33

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 13.69 \quad \underline{\text{USE 9 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 43467$$

$$V_s = 1.687 V_K = 15.201$$

$$R_n = \frac{V_s L}{\rho} = \frac{(15.201)(620)}{1.2791 \times 10^{-5}} = 7.368 \times 10^8$$

$$C_f = 1.590 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.5 \times 10^{-3}}{C_{fT}} = 2.09 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_s^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (59,630) (15.201)^2 (2.09 \times 10^{-3}) \\ &= 28661 \end{aligned}$$

$$R_R = R_T - R_F = 14806$$

$$C_R = \frac{(14806)}{\frac{1}{2} \rho (59,630) (15.201)^2}$$

$$C_R = 1.08$$

CONSTANT C_R FOR SHIP SPEEDS
LESS THAN 9 KT.

DESIGN CALCULATION SHEET

Sheet 70 of 118

Subject HULL RESISTANCE CALCULATION - AS-33Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 10/28/75 Checked

Reviewed

SHIP - AS-33

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (620)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—					0	0
1	1.689	0.8187	2.131	0.5	1.08	3.711	628	0.028
2	3.378	1.637	1.935	"	"	3.515	2380	0.107
3	5.067	2.456	1.832	"	"	3.412	5199	0.234
4	6.756	3.275	1.764	"	"	3.344	9058	0.407
5	8.445	4.093	1.714	"	"	3.294	13942	0.637
6	10.134	4.912	1.674	"	"	3.254	19832	0.891
7	11.823	5.731	1.641	"	"	3.221	26720	1.201
8	13.512	6.549	1.614	"	"	3.194	34608	1.555
9	15.201	—	—	—	—	—	43467	1.954
10	16.89	—	—	—	—	—	45640	2.051
11	18.579	—	—	—	—	—	56309	2.531
12	20.268	—	—	—	—	—	65200	2.930
13	21.957	—	—	—	—	—	77800	4.396

BAD
DATA

[illegible]

Subject HULL RESISTANCE CALCULATION - AKA - 113

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 3/4/76 Checked

Reviewed

SHIP -

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.90 \text{ USE } 11 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 41900$$

AT 11 KT.

$$V_S = 1.687 V_K = 18.579$$

$$R_n = \frac{V_S L}{D} = \frac{(18.579)(550)}{1.2791 \times 10^{-5}} = 7.989 \times 10^8$$

$$C_f = 1.574 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.5 \times 10^{-3}}{C_{fT}} = 2.074 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (50,447) (18.579)^2 (2.074 \times 10^{-3}) \\ &= 35944 \end{aligned}$$

$$R_R = R_T - R_F = 12956$$

$$C_R = \frac{(12956)}{\frac{1}{2} \rho (50447) (18.579)^2}$$

$$C_R = 0.748 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{11 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - AKA 113Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (550)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	
1	1.687	0.7262	2.168	0.5	0.748	3.416	489	0.03
2	3.378	1.453	1.967	"	"	3.215	1842	0.096
3	5.067	2.179	1.862	"	"	3.110	4009	0.21
4	6.756	2.905	1.797	"	"	3.040	6967	0.36
5	8.445	3.631	1.740	"	"	2.988	10699	0.56
6	10.134	4.358	1.700	"	"	2.948	15200	0.79
7	11.823	5.084	1.667	"	"	2.915	20458	1.06
8	13.512	5.81	1.638	"	"	2.886	26455	1.38
9	15.201	6.537	1.614	"	"	2.862	33203	1.72
10	16.89	7.263	1.593	"	"	2.841	40691	2.12
11	18.579	7.989	1.574	"	"	—	48900	2.54
12	20.268	8.715	1.557	"	"	—	57593	2.99
13	21.957	9.441	1.542	"	"	—	66955	3.48

[illegible]

Subject HULL RESISTANCE CALCULATION - LHAShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 14.55 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 39120$$

(AT 10 KT.)

$$V_S = 1.687 V_K = 16.89$$

$$R_n = \frac{V_S L}{\nu} = \frac{(16.89)(700)}{1.2791 \times 10^{-5}} = 9.243 \times 10^8$$

$$C_f = 1.546 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.2 \times 10^{-3}$$

$$C_{fT} = 1.746 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (64,790) (16.89)^2 (1.746 \times 10^{-3}) \\ &= 32118 \end{aligned}$$

$$R_R = R_T - R_F = 7002$$

$$C_R = \frac{(7002)}{\frac{1}{2} \rho (64,790) (16.89)^2}$$

$$C_R = 0.341 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{10 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - LHAShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDOPrepared by RCSDate 3/4/76

Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (700)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	—
1	1.689	0.9243	2.095	0.2	0.381	2.676	492	0.02
2	3.378	1.849	1.904	"	"	2.485	1628	0.08
3	5.067	2.773	1.803	"	"	2.384	3947	0.18
4	6.756	3.697	1.736	"	"	2.317	6319	0.31
5	8.445	4.622	1.687	"	"	2.268	10430	0.47
6	10.134	5.546	1.648	"	"	2.229	14761	0.67
7	11.823	6.470	1.616	"	"	2.197	19803	0.90
8	13.512	7.395	1.589	"	"	2.170	25547	1.16
9	15.201	8.319	1.566	"	"	2.147	31990	1.45
10	16.89	9.243	1.546	"	"	—	39120	1.77
11	18.579	10.167	1.527	"	"	—	47418	2.15
12	20.268	11.091	1.512	"	"	—	59267	2.71
13	21.957	12.016	1.497	"	"	—	—	—

DESIGN CALCULATION SHEET

No. 3419

Sheet 77 of 113

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project *EMERGENCY TOWING GEAR CRITERIA*

Section ESDD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: AO-93

DATA SOURCE : RESISTANCE DATA NOT AVAILABLE

SHIP CHARACTERISTICS

LWL = 502

B = 68

$$T = 30.17^\circ$$
$$\Delta = \underline{21,880}$$

WS = 7

$$C_D = 0.752$$
$$EHP/SHP =$$
$$\Delta C_F = \underline{\underline{0.0004}}$$
$$C_X = 0.9882$$
$$C_B = 0.74$$

PROPELLER CHARACTERISTICS

DIA. = _____

PITC4 =

* BLADES =

EXP. A. / D.A. = _____

EXPANDED AREA = _____

DEVELOPED AREA =

PROJ. AREA / D.A. =

PROJECTED AREA =

PROPELLERS = _____

[illegible]

DESIGN CALCULATION SHEET

No. 711

Sheet 78 of 118

Subject TAYLOR STANDARD SERIES - RESISTANCE CALCULATION

Ship or Project TOWING RESISTANCE CRITERIA

Section Prepared by RCS Date 3/5/76 Checked Reviewed

CALCULATION OF BARE HULL RESISTANCE USING THE
TAYLOR STANDARD SERIES

SHIP CLASS AO-93

WATERLINE LENGTH $L = 502$ BEAM $B = 68$ DRAFT $H = 30.17$ DISPLACEMENT $\Delta = 21880$ IMMERSED VOLUME $V = 765800$ WETTED SURFACE $S = 52449$ IF S IS NOT GIVEN THEN CALCULATE BY EQUATION

$$S = C_s \sqrt{V \cdot L W/L}$$

(FOR C_s COEFFICIENTS SEE REF. 4)BEAM - DRAFT RATIO $B/H = 2.25$ LONG'L PRISMATIC $C_p = 0.752$ VOLUMETRIC COEFFICIENT $C_v = V/L^3 = 6.05 \times 10^{-3}$ WETTED SURFACE COEFFICIENT $C_s = S/\sqrt{V L} = 2.675$ $\Delta C_p = 0.0004$

$$K = \frac{3.00 - B/H}{0.75} = 1.00$$

NOTE: SCHOENHERR'S FRICTIONAL FORMULATIONS ARE USED
TO OBTAIN C_p

$$R_e = \frac{1.687 V_k(L)}{\gamma}$$

 $C_R = 0.56 \times 10^{-3}$ from
TAYLOR'S SERIES

$$R_T = \frac{1}{2} \rho S V_k^2 (1.687)^2 C_t$$

WHERE $\gamma = 1.2791 \times 10^{-5}$
WHERE $\rho = 1.9905$

Subject HULL RESISTANCE CALCULATION - A093Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/5/76 Checked

Reviewed

SHIP -

$$R_{hs} = \frac{V_s L}{\gamma} = \frac{V_s (502)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0				USING TAYLOR'S SERIES		0	0
1	1.689	0.6629	2.197	0.4	0.56	3.157	470	0.02
2	3.378	1.326	1.992	"	"	2.952	1758	0.08
3	5.067	1.989	1.885	"	"	2.845	3213	0.17
4	6.756	2.651	1.814	"	"	2.774	4609	0.30
5	8.445	3.314	1.762	"	"	2.722	10133	0.46
6	10.134	3.977	1.720	"	"	2.68	14367	0.66
7	11.823	4.64	1.686	"	"	2.646	19307	0.88
8	13.512	5.303	1.656	"	"	2.616	24931	1.14
9	15.201	5.966	1.633	"	"	2.593	31276	1.43
10	16.89	6.629	1.611	"	"	2.571	38285	1.75
11	18.579	7.292	1.592	"	"	2.552	45983	2.10
12	20.268	7.954	1.575	"	"	2.535	54359	2.48
13	21.957	8.617	1.559	"	"	2.519	63393	2.90

Sheet 80 of 118

Section BEDD Prepared by RCS Date 3/2/76 Checked _____ Reviewed _____

DATA SOURCE : REF. 1

PROPELLER CHARACTERISTICS

$$C_B = 0.60$$

PROPELLERS = 4

[illegible]

Subject HULL RESISTANCE CALCULATION - CVA(N) - 65

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BCDD

Prepared by RCS

Date 3/4/76 Checked

Reviewed

SHIP -

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 17.73 \text{ KT, } \underline{\text{USE 14 KT.}}$$

$$R_T = \frac{EHP \cdot 1.326}{V_K} = 279429 \text{ (AT 14 KT.)}$$

$$V_S = 1.687 V_K = 23.646$$

$$R_n = \frac{V_S L}{V} = \frac{(23.65)(1040)}{1.2771 \times 10^{-5}} = 1.923 \times 10^9$$

$$C_F = 1.415 \times 10^{-3} \quad (\text{SCHOENHERZ COEFF.})$$

$$\Delta C_F = 0.76 \times 10^{-3}$$

$$C_{FT} = 2.175 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{FT} \\ &= \frac{1}{2} (1.9705) (156,990) (23.65)^2 (2.175 \times 10^{-3}) \\ &= 190075 \end{aligned}$$

$$R_R = R_T - R_F = 89354$$

$$C_R = \frac{(89354)}{\frac{1}{2} \rho (156,990) (23.65)^2}$$

$$C_R = 1.022 \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{14 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 82 of 11

Subject HULL RESISTANCE CALCULATION - CVA(N) - 65Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDNPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

$$R_{hs} = \frac{V_s L}{V} = \frac{V_s (1040)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{hs} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	
1	1.689	1.373	1.982	0.76	1.022	3.764	1678	0.02
2	3.378	2.747	1.805	"	"	3.587	6395	0.07
3	5.067	4.120	1.712	"	"	3.494	14016	0.16
4	6.756	5.493	1.65	"	"	3.432	24475	0.29
5	8.445	6.866	1.604	"	"	3.386	37730	0.44
6	10.134	8.240	1.568	"	"	3.350	53754	0.63
7	11.823	9.613	1.538	"	"	3.320	72510	0.85
8	13.512	10.99	1.513	"	"	3.295	93994	1.10
9	15.201	12.36	1.492	"	"	3.274	118203	1.38
10	16.89	13.73	1.473	"	"	3.255	145082	1.70
11	18.579	15.11	1.456	"	"	3.238	174632	2.04
12	20.268	16.48	1.441	"	"	3.223	206865	2.42
13	21.957	17.85	1.427	"	"	3.209	241724	2.83

no. 711
Sheet 83 of 118

Ship or Project *EMERGENCY TOWING GEAR CRITERIA*

Section BDD Prepared by RCS Date 3/2/76 Checked _____ Reviewed _____

SHIP CLASS: CVA 59

DATA SOURCE : REF. 1

PROPELLER CHARACTERISTICS

$$LWL = 990$$
$$B = 129.33'$$
$$T = 32.65$$
$$\Delta = \underline{72,000}$$

WS = 147.700

$$C_p = \underline{\hspace{2cm}}$$
$$ENP/USD =$$
$$\Delta C_F = 0.002778$$
$$C_A = 0.60$$

DIA. = 21.0

Pitch = 24.87

* BLADES = 5

$$\text{EXP. A. / D.A.} = \underline{0.791}$$

EXPANDED AREA = _____

DEVELOPED AREA = _____

$$\text{PROJ. AREA} / D.A. =$$

PROTECTED AREA =

PROPELLERS = 4

[illegible]

Subject HULL RESISTANCE CALCULATION - CVA 59
 Ship or Project EMERGENCY TOWING GEAR CRITERIA
 Section BSDD Prepared by RCS Date 3/4/76 Checked _____ Reviewed _____

SHIP-

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 17.31 \quad \underline{\text{USE 14 KT.}}$$

$$R_T = \frac{EHP \cdot 1326}{V_K} = 232857$$

$$V_S = 1.687 V_K = 23.65$$

$$R_n = \frac{V_S L}{V} = \frac{(23.65)(990)}{1.2771 \times 10^{-5}} = 1.8302 \times 10^9$$

$$C_f = 1.423 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.778 \times 10^{-3}}{C_{fT}}$$

$$C_{fT} = 2.201 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (147,700) (23.65)^2 (2.201 \times 10^{-3}) \\ &= 180965 \end{aligned}$$

$$R_R = R_T - R_F = 51891$$

$$C_R = \frac{(51891)}{\frac{1}{2} \rho (147,700) (23.65)^2}$$

$$C_R = 0.631 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{14 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - CVA 59Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDNPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP - CVA 59

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (990)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	1.307	1.996	0.778	0.631	3.405	419	0.006
2	3.378	2.615	1.817	"	"	3.226	5411	0.075
3	5.067	3.922	1.723	"	"	3.132	11820	0.16
4	6.756	5.229	1.660	"	"	3.069	20592	0.29
5	8.445	6.536	1.614	"	"	3.023	31692	0.44
6	10.134	7.843	1.578	"	"	2.987	45093	0.63
7	11.823	9.151	1.548	"	"	2.957	60760	0.84
8	13.512	10.46	1.523	"	"	2.932	78689	1.09
9	15.201	11.77	1.501	"	"	2.910	98944	1.37
10	16.89	13.07	1.481	"	"	2.89	121191	1.68
11	18.579	14.38	1.464	"	"	2.873	145778	2.02
12	20.268	15.69	1.449	"	"	2.858	172582	2.40
13	21.957			"	"			

DESIGN CALCULATION SHEET

Subject HULL RESISTANCE & PROPELLER DATA SHEETShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/2/76

Checked

Reviewed

SHIP CLASS: LCU FYDATA SOURCE: REPORT 178-H-02, MODEL 5090, FEB. 1967
(SHIP HAS NOZZLES FITTED)SHIP CHARACTERISTICS

LWL = 120.7
 B = 29
 T = 5.12
 Δ = 375
 WS = 3941
 C_p = 0.729
 EHP/SHIP =
 ΔC_F = 0.00145
 C_B = 0.709

PROPELLER CHARACTERISTICS

DIA. = 4.0
 PITCH =
 # BLADES = 4
 EXP. A./D.A. =
 EXPANDED AREA =
 DEVELOPED AREA =
 PROJ. AREA/D.A. =
 PROJECTED AREA =
 # PROPELLERS = 2

V KNOTS	SHIP	EHP/SHIP	EHP	$R_T = \frac{326(EHP)}{V_k}$ POUNDS	EHP ERIC.
4			10	815	
5			18	1174	
6			35	1902	
7			63	2934	
8			100	4075	
9			155	5614	
10			236	7694	
11			345	10225	
12			510	13855	
13			725	18181	

Subject HULL RESISTANCE CALCULATION - LCU FYShip or Project EMERGENCY TOWING GEAR CRITERIASection BCDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP - LCU FY

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 6.04 \text{ USE } 4 \text{ KT.}$$

$$R_T = \frac{EHP \times 326}{V_K} = 815 \text{ (AT } 4 \text{ KT.)}$$

$$V_s = 1.687 V_K = 6.756$$

$$R_n = \frac{V_s L}{\rho} = \frac{(6.756)(120.7)}{1.2791 \times 10^{-5}} = 6.375 \times 10^7$$

$$C_f = 2.209 \times 10^{-3} \text{ (SCHOENHERR COEFF.)}$$

$$\Delta C_f = \frac{1.45 \times 10^{-3}}{C_f}$$

$$C_{fT} = 3.659 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_s^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (3941) (6.756)^2 (3.659 \times 10^{-3}) \\ &= 655 \end{aligned}$$

$$R_R = R_T - R_F = 160$$

$$C_R = \frac{(160)}{\frac{1}{2} \rho (3941) (6.756)^2}$$

$$C_R = 0.893$$

CONSTANT C_R FOR SHIP SPEEDS
LESS THAN 4 KT.

Subject HULL RESISTANCE CALCULATION - LCU FYShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDOPrepared by RCSDate 3/6/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (120.7)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	—
1	1.689	0.1594	2.723	1.45	0.893	5.066	56.7	0.15
2	3.378	0.3188	2.447	"	"	4.790	214	0.57
3	5.067	0.4781	2.304	"	"	4.647	468	1.25
4	6.756	—	—	—	—	—	815	2.17
5	8.445	—	—	—	—	—	1174	3.13
6	10.134	—	—	—	—	—	1902	5.07
7	11.823	—	—	—	—	—	2934	7.82
8	13.512	—	—	—	—	—	4075	10.87
9	15.201	—	—	—	—	—	5614	14.97
10	16.89	—	—	—	—	—	7694	20.52
11	18.579	—	—	—	—	—	10225	27.27
12	20.268	—	—	—	—	—	13855	36.95
13	21.957	—	—	—	—	—	18181	48.48

PROPELLERS = 1

[illegible]

DESIGN CALCULATION SHEET

Sheet 90 of 118

Subject TAYLOR STANDARD SERIES - RESISTANCE CALCULATIONShip or Project TOWING RESISTANCE CRITERIA

Section

Prepared by RCSDate 12/10/75 Checked

Reviewed

CALCULATION OF BARE HULL RESISTANCE USING THE
TAYLOR STANDARD SERIESSHIP CLASS FF 1052 OR DE 1052WATERLINE LENGTH $L =$ 419BEAM $B =$ 46.6DRAFT $H =$ 25DISPLACEMENT $\Delta =$ 4200IMMERSED VOLUME $\nabla =$ 147000WETTED SURFACE $S =$ 21818IF S IS NOT GIVEN THEN CALCULATE BY EQUATION

$$S = C_S \sqrt{\nabla \cdot L W/L}$$

(FOR C_S COEFFICIENTS SEE REF. 4)BEAM - DRAFT RATIO $B/H =$ 1.86LONG'L PRISMATIC $C_p =$ 0.577VOLUMETRIC COEFFICIENT $C_v = \nabla/L^3 =$ 1.998×10^{-3} WETTED SURFACE COEFFICIENT $C_s = S/\sqrt{\nabla L} =$ 2.78

$$\Delta C_f =$$

$$K = \frac{3.00 - B/H}{0.75} =$$

NOTE: SCHOENHERR'S FRICTIONAL FORMULATIONS ARE USED
TO OBTAIN C_f

$$R_e = \frac{1.657 V_k(L)}{\gamma}$$

$$\text{WHERE } \gamma = 1.2791 \times 10^{-5}$$

$$R_T = \frac{1}{2} \rho S V_k^2 (1.657)^2 C_e$$

$$\text{WHERE } \rho = 1.9905$$

AD-A150 941

DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE
DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U)
ROSENBLATT (M) AND SON INC NEW YORK APR 76

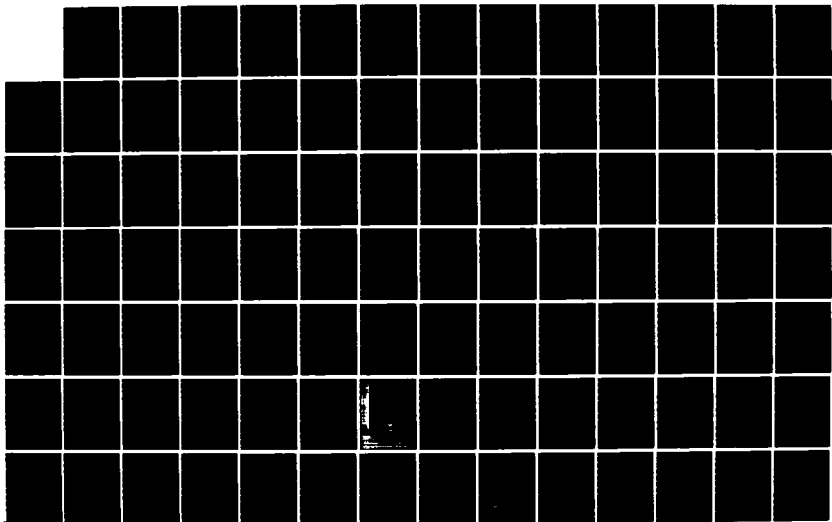
3/6

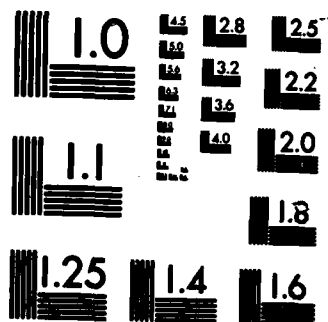
UNCLASSIFIED

N00024-74-C-5508

F/G 13/10

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Subject HULL RESISTANCE CALCULATION - FF 1052Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 2/13/76 Checked

Reviewed

SHIP-

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 11.25$$

$$R_T = \frac{EHP \times 326}{V_K} = \frac{44P \times 326}{11.25} = 60853$$

TAYLOR'S SERIES INDICATES THAT
 C_R IS CONSTANT BELOW $V/V_K = 0.7$
AT 15 KT.

$$V_S = 1.687 V_K = 25.335$$

$$R_n = \frac{V_S L}{\nu} = \frac{(25.335)(419)}{1.2771 \times 10^{-5}} = 8.299 \times 10^8$$

$$C_f = 1.567 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{0.6 \times 10^{-3}}{C_{fT}} = 2.167 \times 10^{-3}$$

$$R_F = \frac{1}{2} \rho S V_S^2 C_{fT} = \frac{1}{2} (1.9905) (21818) (25.335)^2 (2.167 \times 10^{-3}) = 30203$$

$$R_R = R_T - R_F = 30650$$

$$C_R = \frac{(30650)}{\frac{1}{2} \rho (21818) (25.335)^2}$$

$$C_R = 2.20 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{15 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 92 of 113

Subject HULL RESISTANCE CALCULATION - FF 1052Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by PCSDate 2/13/76

Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\nu} = \frac{V_s (419)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	0.553	2.255	0.6	2.20	5.055	313	0.08
2	3.378	1.107	2.043	"	"	4.843	1200	0.29
3	5.067	1.660	1.932	"	"	4.732	2638	0.63
4	6.756	2.213	1.858	"	"	4.658	4617	1.10
5	8.445	2.766	1.803	"	"	4.603	7128	1.70
6	10.134	3.320	1.761	"	"	4.561	10171	2.42
7	11.823	3.873	1.726	"	"	4.526	13738	3.27
8	13.512	4.426	1.696	"	"	4.496	17824	4.24
9	15.201	4.979	1.671	"	"	4.471	22433	5.34
10	16.89	5.533	1.649	"	"	4.449	27559	6.56
11	18.579	6.086	1.629	"	"	4.429	33197	7.90
12	20.268	6.639	1.611	"	"	4.411	39346	9.37
13	21.957	7.192	1.595	"	"	4.395	46010	10.95

Subject HULL RESISTANCE CALCULATION - DDG-2Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 2/13/76 Checked

Reviewed

SHIP-

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 11.42$$

$$R_T = \frac{ENP \cdot 1326}{V_K} = 40,750$$

TAYLOR'S SERIES INDICATES C_R IS
CONSTANT AT $V/K = 0.58 \approx 12$ K.

$$V_S = 1.687 V_K = 20.268$$

$$R_n = \frac{V_S L}{\rho} = \frac{(20.268)(431)}{1.2771 \times 10^{-5}} = 6.829 \times 10^8$$

$$C_f = 1.605 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{1.10 \times 10^{-3}}{C_{fT} = 2.705 \times 10^{-3}}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (22470) (20.268)^2 (2.705 \times 10^{-3}) \\ &= 24850 \end{aligned}$$

$$R_R = R_T - R_F = 15900$$

$$C_R = \frac{(15900)}{\frac{1}{2} \rho (22470) (20.268)^2}$$

$$C_R = 1.73 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{12 \text{ KT.}}$$

DESIGN CALCULATION SHEET

Sheet 95 of 116

Subject HULL RESISTANCE CALCULATION - DDG-2Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 2/13/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (431)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	0
1	1.689	0.569	2.246	1.10	1.73	5.076	324	0.071
2	3.378	1.138	2.035	"	"	4.865	1241	0.27
3	5.067	1.707	1.929	"	"	4.759	2730	0.60
4	6.756	2.276	1.851	"	"	4.681	4778	1.05
5	8.445	2.846	1.797	"	"	4.627	7380	1.62
6	10.134	3.415	1.759	"	"	4.584	10528	2.32
7	11.823	3.984	1.720	"	"	4.55	14223	3.13
8	13.512	4.553	1.690	"	"	4.52	18455	4.06
9	15.201	5.122	1.665	"	"	4.495	23228	5.11
10	16.89	5.691	1.643	"	"	4.473	28536	6.28
11	18.579	6.260	1.623	"	"	4.453	34374	7.56
12	20.268	6.829	1.605	"	"	4.435	40742	8.97
13	21.957	7.399	1.589	"	"	4.419	47643	10.48

Sheet 96 of 118

Ship or Project EMERGENCY TOWING GEAR CRITICIN

Section B3DD Prepared by _____ Date _____ Checked _____ Reviewed _____

SHIP CLASS: DD 963

DATA SOURCE : DON CALLUM - TRIAL CONDITION 4 MODEL 5265-1
BY LIN AND MURRAY JAN. 1975.

PROPELLER CHARACTERISTICS

$$\begin{aligned}LWL &= 530.2 \\B &= 55.0 \\T &= 19.74 \\\Delta &= 8000 \\WS &= 35410 \\C_p &= 0.5804 \\ENP/540 &= \dots \\\Delta C_F &= 0.0005 \\C_B &= 0.49\end{aligned}$$

DIA. = 17.00
PITCH = 26.18
BLADES = 5
EXP. A. / D.A. = 0.730
EXPANDED AREA = _____
DEVELOPED AREA = _____
PROJ. AREA / D.A. = _____
PROJECTED AREA = _____
PROPELLERS = 2

[illegible]

Subject HULL RESISTANCE CALCULATION - DD 963Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/3/76 Checked

Reviewed

SHIP -

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.66 \text{ KT.}$$

$$R_T = \frac{EHP \cdot 1.326}{V_K} = 105950 \quad \text{AT } V/V_K = 0.69 \quad C_R \text{ IS STILL CONSTANT}$$

$$V_S = 1.687 \quad V_K = 27.024$$

$$R_n = \frac{V_S L}{\nu} = \frac{(27.024)(530.2)}{1.2771 \times 10^{-5}} = 1.1202 \times 10^9$$

$$C_f = 1.51 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.5 \times 10^{-3}}{C_f}$$

$$C_{fT} = 2.01 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (35410) (27.024)^2 (2.01 \times 10^{-3}) \\ &= 51731 \end{aligned}$$

$$R_R = R_T - R_F = 54219$$

$$C_R = \frac{(54219)}{\frac{1}{2} \rho (35410) (27.024)^2}$$

$$C_R = 2.107 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{16 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - DD 963Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDOPrepared by RCSDate 3/3/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (530.2)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T / Δ
0	0						0	0
1	1.689	0.700	2.100	0.5	2.107	4.787	481	0.06
2	3.378	1.400	1.977	"	"	4.589	1843	0.23
3	5.067	2.100	1.871	"	"	4.478	4052	0.51
4	6.756	2.800	1.801	"	"	4.408	7091	0.88
5	8.445	3.500	1.749	"	"	4.356	10948	1.37
6	10.134	4.201	1.708	"	"	4.315	15617	1.95
7	11.823	4.900	1.674	"	"	4.281	21089	2.64
8	13.512	5.601	1.646	"	"	4.253	27365	3.42
9	15.201	6.301	1.622	"	"	4.229	34438	4.30
10	16.89	7.001	1.600	"	"	4.207	42295	5.29
11	18.579	7.701	1.581	"	"	4.188	50946	6.37
12	20.268	8.401	1.564	"	"	4.171	60384	7.55
13	21.957	9.101	1.549	"	"	4.156	70612	8.83

nu. -711
Sheet 99 of 118

nu. -711
Sheet 99 of 118

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BEDD

Prepared by RCS

Date 3/2/76 Checked

Checked

Reviewed

SHIP CLASS: T-AGOR

DATA SOURCE : MODEL 5042 REPORT 072-14-08 Nov. 1966

SHIP CHARACTERISTICS

$$\begin{aligned}LWL &= 220 \\B &= 46 \\T &= 15 \\\Delta &= 1922 \\WS &= 11107 \text{ (BARE HULL)} \\C_P &= \\C_{FP}/SHP &= \\\Delta C_F &= 0.0005 \\C_B &= 0.44\end{aligned}$$

PROPELLER CHARACTERISTICS

CYCLOIDAL PROPELLERS

DIA. = _____

PITCH = _____

* BLADES = _____

EXP. A. / D.A. = _____

EXPANDED AREA = _____

DEVELOPED AREA = _____

PROJ. AREA / D.A. = _____

PROJECTED AREA = _____

* PROPELLERS = _____

[illegible]

Subject HULL RESISTANCE CALCULATION - T-AGORShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{V_{LWL}} = 8.16 \quad \underline{\text{USE 7 KT.}}$$

$$R_T = \frac{EHP \times 326}{V_K} = 4890 \quad (\text{AT 7 KT.})$$

$$V_S = 1.687 V_K = 11.823$$

$$R_n = \frac{V_S L}{V} = \frac{(11.823)(220)}{1.2791 \times 10^{-5}} = 2034 \times 10^8$$

$$C_f = 2.621 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.5 \times 10^{-3}}{C_{fT}} = 3.121 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (11107) (11.823)^2 (3.121 \times 10^{-3}) \\ &= 4823 \end{aligned}$$

$$R_R = R_T - R_F = 67$$

$$C_R = \frac{(67)}{\frac{1}{2} \rho (11107) (11.823)^2}$$

$$C_R = 0.043 \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{7 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - T-A602

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by RCS

Date 3/4/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (220)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	—
1	1.689	0.2905	2.482	0.5	0.043	3.025	95.39	0.25
2	3.378	0.5810	2.239	"	"	2.782	351	0.18
3	5.067	0.8715	2.112	"	"	2.655	754	0.39
4	6.756	1.162	2.029	"	"	2.572	1298	0.68
5	8.445	1.453	1.967	"	"	2.510	1979	1.03
6	10.134	1.743	1.919	"	"	2.462	2795	1.45
7	11.823	—	—	—	—	—	4890	2.54
8	13.512	—	—	—	—	—	6805	3.54
9	15.201	—	—	—	—	—	8802	4.58
10	16.89	—	—	—	—	—	10,856	5.65
11	18.579	—	—	—	—	—	13,336	6.94
12	20.268	—	—	—	—	—	16,436	8.55
13	21.957	—	—	—	—	—	—	—

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BSDD

Prepared by

Date 2/12/76 Checked

Reviewed

SHIP CLASS: DLG-26 (CG-26)

DATA SOURCE :

SHIP CHARACTERISTICS

$$LWL = 524.6$$
$$B = \underline{54.4}$$
$$T = 19.1$$
$$\Delta = \underline{\underline{7.928}}$$

WS = 34.620

$$C_p = \underline{0.618}$$
$$EHP/S4P =$$
$$\Delta C_F = \underline{\underline{0.0006}}$$

PROPELLER CHARACTERISTICS

DIA. = 14.75

Pitch = 16.58

* BLADES = 6

$$\text{EXP. A. / D.A.} = \underline{1.035}$$

EXPANDED AREA = _____

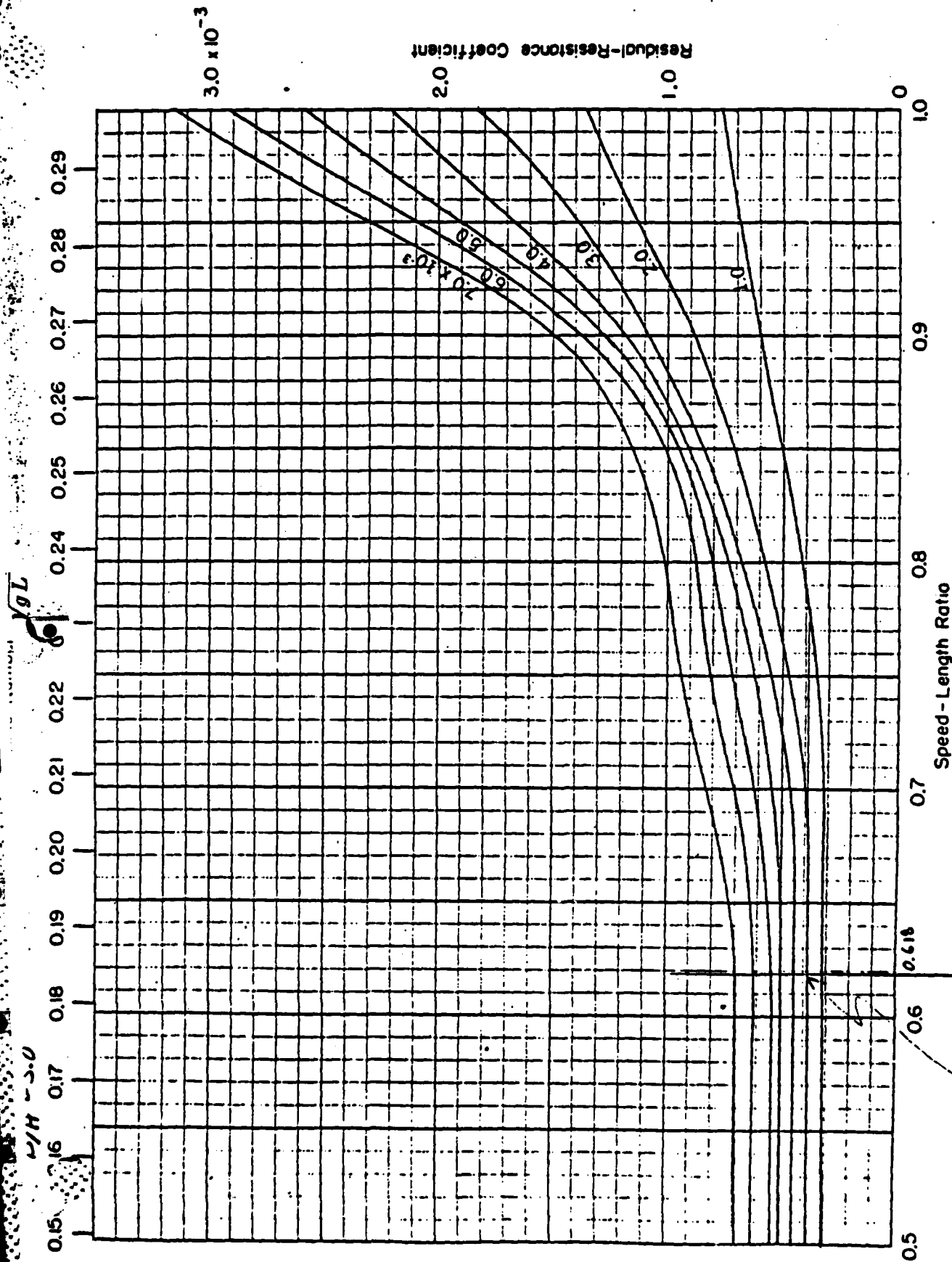
DEVELOPED AREA = _____

PROJ. AREA / D A =

PROJECTED AREA = 296

PROPELLERS = 2

[illegible]



DESIGN CALCULATION SHEET

Subject HULL RESISTANCE CALCULATION - DLG-26 (CG-26)
 Ship or Project EMERGENCY TOWING GEAR CRITERIA
 Section BSDD Prepared by RCS Date 2/12/76 Checked _____ Reviewed _____

SHIP - DLG-26

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.59$$

HOWEVER TAYLOR'S SERIES C_R IS CONSTANT BELOW

$$R_T = \frac{EHP \times 326}{V_K} = 67529 \quad \sqrt[4]{V_K} = 0.61 \approx 14 \text{ KT.}$$

AT 14 KT.

$$V_S = 1.687 V_K = 23.646$$

$$R_n = \frac{V_S L}{\nu} = \frac{(23.646)(524.6)}{1.2771 \times 10^{-5}} = 9.698 \times 10^8$$

$$C_f = 1.537 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{0.6 \times 10^{-3}}{C_f}$$

$$C_{fT} = 2.137 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (34,620) (23.646)^2 (2.137 \times 10^{-3}) \\ &= 41170 \end{aligned}$$

$$R_R = R_T - R_F = 26359$$

$$C_R = \frac{(26359)}{\frac{1}{2} \rho (34,620) (23.646)^2}$$

$$C_R = 1.368 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{14 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - DLG-26 (CG-26)Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDN

Prepared by

RCSDate 2/12/76 Checked

Reviewed

SHIP - DLG-26

$$R_{NS} = \frac{V_S L}{\gamma} = \frac{V_S (524.6)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_S FT./SEC.	R_{NS} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.693	2.183	0.60	1.368	4.151	215	0.027
2	3.378	1.385	1.980	"	"	3.948	1552	0.196
3	5.067	2.078	1.874	"	"	3.842	3399	0.429
4	6.756	2.771	1.803	"	"	3.771	5931	0.748
5	8.445	3.463	1.751	"	"	3.719	9139	1.15
6	10.134	4.156	1.709	"	"	3.677	13011	1.64
7	11.823	4.849	1.677	"	"	3.645	17555	2.21
8	13.512	5.541	1.648	"	"	3.616	22747	2.87
9	15.201	6.234	1.624	"	"	3.592	28,598	3.61
10	16.89	6.927	1.602	"	"	3.570	35,090	4.43
11	18.579	7.620	1.583	"	"	3.551	42,233	5.33
12	20.268	8.313	1.566	"	"	3.534	50020	6.31
13	21.957	9.005	1.551	"	"	3.519	58455	7.37

no. 2417
Sheet 106 of 118

Section BSDD Prepared by _____ Date 2/12/76 Checked _____ Reviewed _____

DATA SOURCE : REPORT: DD 692 CLASS LENGTHENED 141
MODEL NUMBER 3869-2

PROPELLER CHARACTERISTICS

PROPELLERS = 2

[illegible]

Subject HULL RESISTANCE CALCULATION - DD 710 4 825Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDD

Prepared by

Date 2/12/76 Checked

Reviewed

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{L_{WL}} = 10.76$$

$$R_T = \frac{EHP \cdot 1.326}{V_K} = 22548 \quad \text{HOWEVER TAYLOR'S SERIES IS CONSTANT BELOW } V/V_K = 0.64 \approx 12 \text{ KT.}$$

($V_K = 12 \text{ KT.}$)

$$V_S = 1.687 V_K = 20.27$$

$$R_n = \frac{V_S L}{V} = \frac{(20.27)(383)}{1.2771 \times 10^{-5}} = 6.069 \times 10^8$$

$$C_f = 1.629 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{1.141 \times 10^{-3}}{C_{fT}}$$

$$C_{fT} = 2.77 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (18673) (20.27)^2 (2.77 \times 10^{-3}) \\ &= 21151 \end{aligned}$$

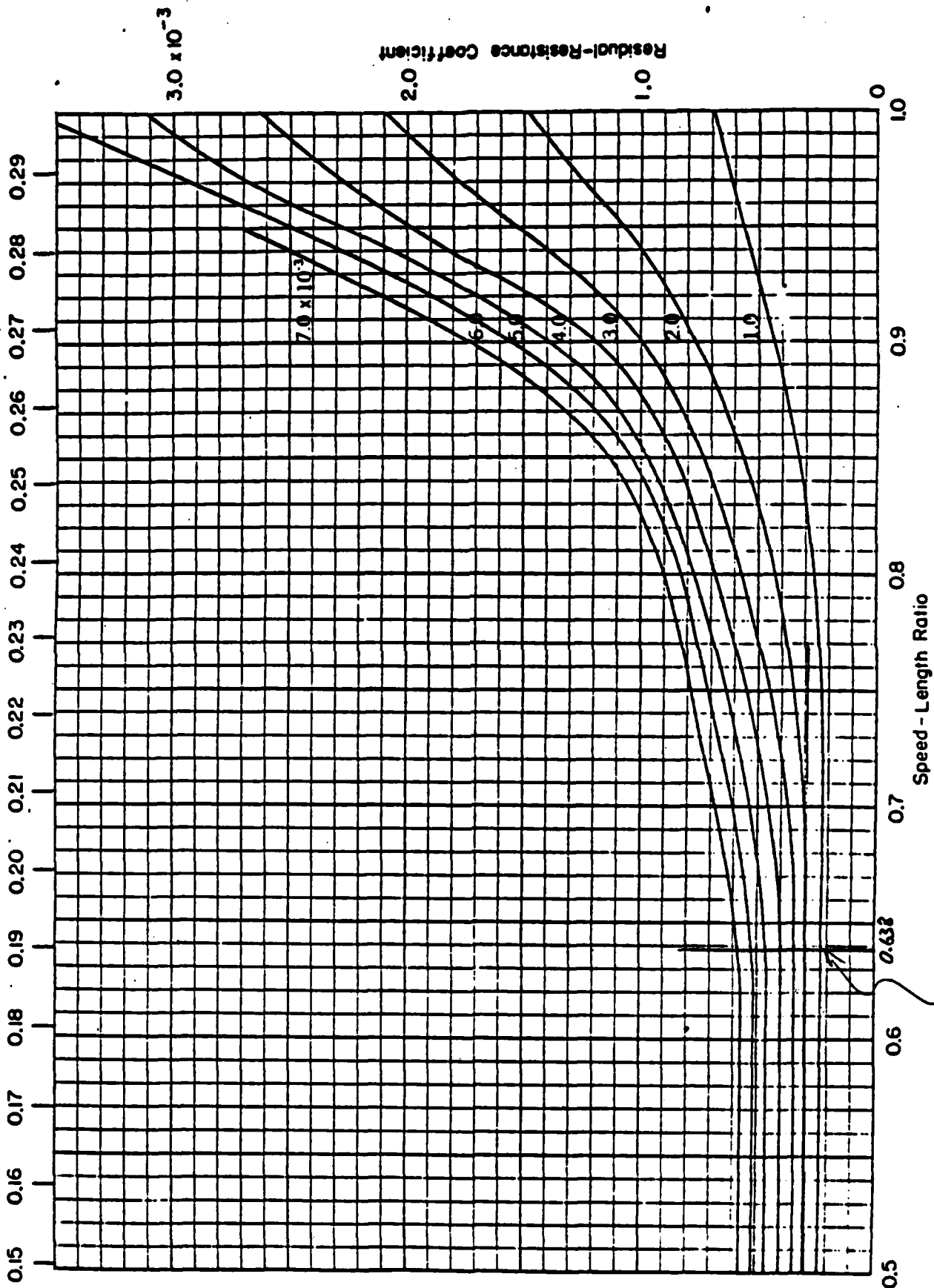
$$R_R = R_T - R_F = 22548 - 21151 = 1396.8$$

$$C_R = \frac{(1396.8)}{\frac{1}{2} \rho (18673) (20.27)^2}$$

$$C_R = 0.183 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{12 \text{ KT.}}$$

B/H = 2.2
C_p = 0.64

Froude Number, $\frac{V}{\sqrt{gL}}$



$V/L = 0.632 = 17 \text{ KT}$

Subject HULL RESISTANCE CALCULATION - DD 710 & 825Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 2/12/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (383)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.687	0.506	2.285	1.141	0.183	3.609	191	0.001
2	3.378	1.011	2.069	"	"	3.393	719	0.211
3	5.067	1.517	1.956	"	"	3.280	1565	0.46
4	6.756	2.023	1.881	"	"	3.205	2719	0.80
5	8.445	2.529	1.825	"	"	3.149	4174	1.23
6	10.134	3.034	1.782	"	"	3.106	5928	1.74
7	11.823	3.540	1.746	"	"	3.070	7975	2.35
8	13.512	4.046	1.716	"	"	3.040	10315	3.03
9	15.201	4.552	1.690	"	"	3.014	12943	3.81
10	16.89	5.057	1.668	"	"	2.992	15862	4.67
11	18.579	5.563	1.648	"	"	2.972	19065	5.61
12	20.268	—	—	—	—	—	22548	6.63
13	21.957	—	—	—	—	—	—	—

Sheet 110 of 118

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BEDD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: DL-1 (ex. CLK1)

DATA SOURCE : REF.1

PROPELLER CHARACTERISTICS

$$LWL = \underline{520}$$
$$B = \underline{\underline{54}}$$
$$T = 18.00$$
$$\Delta = \underline{\underline{6625}}$$
$$WS = \underline{31685}$$
$$C_p =$$
$$ENP'/S4P =$$
$$\Delta C_F = \underline{\underline{0.000923}}$$
$$C_B = 0.46$$

DIA. = 18'-4"

$P_{ITC4} = 22.5$

BLADES = 6

EXP. A. / D.A. = _____

EXPANDED AREA = _____

DEVELOPED AREA = _____

$$\text{PROJ. AREA} / D.A. = 0.706$$

PROJECTED AREA = 186.37

PROPELLERS = 2

[illegible]

Subject HULL RESISTANCE CALCULATION - DL-1
 Ship or Project EMERGENCY TOWING GEAR CRITERIA
 Section BSDD Prepared by RCS Date 3/4/76 Checked _____ Reviewed _____

SHIP -

CALCULATION FOR MAX. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{L_{WL}} = 12.54 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \cdot 1326}{V_K} = 32600$$

$$V_S = 1.689 V_K = 16.89$$

$$R_n = \frac{V_S L}{\rho} = \frac{(16.89)(520)}{1.2771 \times 10^{-5}} = 6.866 \times 10^{-3}$$

$$C_f = 1.604 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = \frac{0.923 \times 10^{-3}}{2.527 \times 10^{-3}}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{FT} \\ &= \frac{1}{2} (1.9905) (32600) (16.89)^2 (2.527 \times 10^{-3}) \\ &= 23389 \end{aligned}$$

$$R_R = R_T - R_F = 9211$$

$$C_R = \frac{(9211)}{\frac{1}{2} \rho (32600) (16.89)^2}$$

$$C_R = 0.995 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{10 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - DL-1Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (520)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—				—	0	0
1	1.689	0.6866	2.185	0.923	0.995	4.103	369	0.06
2	3.378	1.373	1.982	"	"	3.900	1403	0.21
3	5.067	2.060	1.876	"	"	3.794	3072	0.46
4	6.756	2.747	1.805	"	"	3.723	5359	0.81
5	8.445	3.433	1.753	"	"	3.671	8256	1.25
6	10.134	4.120	1.712	"	"	3.63	11756	1.77
7	11.823	4.806	1.678	"	"	3.596	15851	2.39
8	13.512	5.493	1.650	"	"	3.568	20542	3.10
9	15.201	6.180	1.626	"	"	3.544	25824	3.89
10	16.89	—	—	—	—	—	32600	4.92
11	18.579	—	—	—	—	—	—	—
12	20.268	—	—	—	—	—	43467	6.56
13	21.957	—	—	—	—	—	—	—

DESIGN CALCULATION SHEET

Sheet 113 of 118

Subject HULL RESISTANCE & PROPELLER DATA SHEETShip or Project EMERGENCY TOWING GEAR CRITERIASection BSDD

Prepared by

RCSDate 3/4/76

Checked

Reviewed

SHIP CLASS: LST 1171DATA SOURCE: REF. 1SHIP CHARACTERISTICS

LWL = 426
 B = 62
 T = 12.29
 Δ = 7084
 WS = 30384
 C_p =
 EHP/SHP =
 ΔC_F = 0.00086

C_B = 0.76PROPELLER CHARACTERISTICS

DIA. = 9.25
 PITCH = 8.35
 # BLADES = 5
 EXP. A./D.A. =
 EXPANDED AREA =
 DEVELOPED AREA = 49.0
 PROJ. AREA/D.A. =
 PROJECTED AREA = 42.8
 # PROPELLERS = 2

V KNOTS	SHP	EHP/SHP	EHP	R _T POUNDS	EHP ERIC.
6			200		
7			350		
8			500		
9			650		
10			950		
11			1200		
12			1600		
13			2250		

Subject

HULL RESISTANCE CALCULATION - LST-1171

Ship or Project

EMERGENCY TOWING GEAR CRITERIA

Section

BSDD

Prepared by

RCS

Date 3/4/76

Checked

Reviewed

SHIP-

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 11.35 \text{ USE } 6 \text{ KT.}$$

$$R_T = \frac{EHP \cdot 326}{V_K} = 10867$$

$$V_S = 1.687 V_K = 10.134$$

$$R_n = \frac{V_S L}{\rho} = \frac{(10.134)(426)}{1.2771 \times 10^{-5}} = 3.375 \times 10^8$$

$$C_f = 1.733 \times 10^{-3} \text{ (SCHOENHERR COEFF.)}$$

$$\Delta C_f = \frac{0.86 \times 10^{-3}}{C_{fT}} = 2.593 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (30384) (10.134)^2 (2.593 \times 10^{-3}) \\ &= 8053 \end{aligned}$$

$$R_R = R_T - R_F = 2814$$

$$C_R = \frac{(2814)}{\frac{1}{2} \rho (30384) (10.134)^2}$$

$$C_R = 0.906$$

CONSTANT C_R FOR SHIP SPEEDS
LESS THAN 6 KT.

Subject HULL RESISTANCE CALCULATION - LST-1171Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (426)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	—
1	1.689	0.5625	2.249	0.86	0.906	4.015	346	0.05
2	3.378	1.125	2.038	"	"	3.804	1313	0.19
3	5.067	1.688	1.927	"	"	3.693	2867	0.40
4	6.756	2.250	1.854	"	"	3.620	4996	0.71
5	8.445	2.813	1.800	"	"	3.566	7691	1.09
6	10.134	—	—	—	—	—	10867	1.53
7	11.823	—	—	—	—	—	16300	2.30
8	13.512	—	—	—	—	—	20375	2.88
9	15.201	—	—	—	—	—	23544	3.32
10	16.89	—	—	—	—	—	30970	4.37
11	18.579	—	—	—	—	—	35564	5.02
12	20.268	—	—	—	—	—	43467	6.14
13	21.957	—	—	—	—	—	56423	7.96

Subject HULL RESISTANCE & PROPELLER DATA SHEET

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section B3DD

Prepared by

Date _____

Checked

Reviewed

SHIP CLASS: LCC-19

DATA SOURCE : REF. 1

SHIP CHARACTERISTICS

LWL = 556

$$B = \underline{82.0}$$
$$T = 26$$
$$\Delta = \underline{\underline{18,500}}$$
$$WS = \underline{\underline{49,540}}$$
$$C_p = \underline{\underline{0.5479}}$$
$$ENP'/S4D =$$
$$\Delta C_F = \underline{\underline{0.0005}}$$
$$C_B = 0.51$$

PROPELLER CHARACTERISTICS

DIA. = 200

$$P_{ITC4} = 24.82$$

BLADES = 4

EXP. A. / D.A. = _____

EXPANDED AREA = 234.54

DEVELOPED AREA = _____

$$\text{PROJ. AREA} / D.A. =$$

PROJECTED AREA = 185.48

PROPELLERS = 1

[illegible]

Subject HULL RESISTANCE CALCULATION - LCC-19
 Ship or Project EMERGENCY TOWING GEAR CRITERIA
 Section BSDD Prepared by RCS Date 3/4/76 Checked _____ Reviewed _____

SHIP-

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.96 \quad \underline{\text{USE 10 KT.}}$$

$$R_T = \frac{EHP \cdot 1325}{V_K} = 44010$$

$$V_S = 1.687 V_K = 16.89$$

$$R_n = \frac{V_S L}{V} = \frac{(16.89)(556)}{1.2771 \times 10^{-5}} = 7342 \times 10^8$$

$$C_f = 1.591 \times 10^{-3} \quad (\text{SCHOENHERR COEFF.})$$

$$\Delta C_f = 0.5 \times 10^{-3}$$

$$C_{fT} = 2.091 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9905) (49,540) (16.89)^2 (2.091 \times 10^{-3}) \\ &= 29410 \end{aligned}$$

$$R_R = R_T - R_F = 14600$$

$$C_R = \frac{(14600)}{\frac{1}{2} \rho (49540) (16.89)^2}$$

$$C_R = 1.038 \times 10^{-3} \quad \text{CONSTANT } C_R \text{ FOR SHIP SPEEDS LESS THAN } \underline{10 \text{ KT.}}$$

Subject HULL RESISTANCE CALCULATION - LCC-19Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{\gamma} = \frac{V_s (556)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_k^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_k^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_k KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0						0	
1	1.689	0.7342	2.165	0.5	1.038	3.703	521	0.03
2	3.378	1.468	1.964	"	"	3.502	1970	0.11
3	5.067	2.203	1.859	"	"	3.397	4300	0.23
4	6.756	2.937	1.789	"	"	3.327	7487	0.40
5	8.445	3.671	1.738	"	"	3.276	11519	0.62
6	10.134	4.405	1.697	"	"	3.235	16380	0.88
7	11.823	5.139	1.664	"	"	3.202	22068	1.19
8	13.512	5.873	1.636	"	"	3.174	28572	1.54
9	15.201	6.608	1.612	"	"	3.150	35887	1.94
10	16.89						44010	2.38
11	18.579						53345	2.88
12	20.268						65200	3.52
13	21.957						75231	4.07

Sheet 1164 of 118

Ship or Project EMERGENCY TOWING GENE CRITFERN

Section B.E.D.D

Prepared by RCS

Date 3/2/76 Checked

Reviewed

SHIP CLASS: LPH-3

DATA SOURCE : REF. 1

SHIP CHARACTERISTICS

$$LWL = 543.22$$
$$B = 84.17$$
$$T = 26.5$$
$$\Delta = 18080$$

WS = 49045

$$C_p =$$
$$ENP' / \epsilon_{4P} =$$
$$\Delta C_F = \underline{\underline{0.00071}}$$
$$C_B = 0.52$$

PROPELLER CHARACTERISTICS

$$D_{IA} = 21.0$$

$P_{TC4} = 22.5$

* BLADES = 4

EXP. A. / D.A. =

EXPANDED AREA =

DEVELOPED AREA =

$$\text{PROJ. AREA} / D.A. =$$

PROTECTED AREA = 155.3

PROPELLERS =

[illegible]

Subject HULL RESISTANCE CALCULATION - LPH-3

Ship or Project EMERGENCY TOWING GEAR CRITERIA

Section BDD

Prepared by RCS

Date 3/4/74 Checked

Reviewed

SHIP -

CALCULATION FOR MIN. SPEED WHERE C_R IS CONSTANT

$$V_K = 0.55 \sqrt{LWL} = 12.91 \quad \text{USE } 8 \text{ KT.}$$

$$R_T = \frac{EHP \ 1326}{V_K} = 28525 \quad (\text{AT } 8 \text{ KT.})$$

$$V_S = 1.689 V_K = 13.512$$

$$R_n = \frac{V_S L}{V} = \frac{(13.512)(543.02)}{1.2791 \times 10^{-5}} = 5.736 \times 10^8$$

$$C_f = 1.641 \times 10^{-3} \quad (\text{SCHÖENHERR COEFF.})$$

$$\Delta C_f = \frac{0.71 \times 10^{-3}}{C_f}$$

$$C_{fT} = 2.351 \times 10^{-3}$$

$$\begin{aligned} R_F &= \frac{1}{2} \rho S V_S^2 C_{fT} \\ &= \frac{1}{2} (1.9705) (49045) (13.512)^2 (2.351 \times 10^{-3}) \\ &= 20952 \end{aligned}$$

$$R_R = R_T - R_F = 7573$$

$$C_R = \frac{(7573)}{\frac{1}{2} \rho (49045) (13.512)^2}$$

$$C_R = 0.850$$

CONSTANT C_R FOR SHIP SPEEDS
LESS THAN 8 KT.

Subject HULL RESISTANCE CALCULATION - LPH-3Ship or Project EMERGENCY TOWING GEAR CRITERIASection BSDDPrepared by RCSDate 3/4/76 Checked

Reviewed

SHIP -

$$R_{ns} = \frac{V_s L}{V} = \frac{V_s (543.02)}{1.2791 \times 10^{-5}}$$

$$R_T = \frac{1}{2} \rho S V_K^2 C_{TS} (1.689)^2$$

$$R_T = \frac{1}{2} (1.9905) S V_K^2 C_{TS} (1.689)^2$$

TABLE FOR CALCULATION OF R_T

V_K KT.	V_s FT./SEC.	R_{ns} $\times 10^8$	C_F $\times 10^{-3}$	ΔC_F $\times 10^{-3}$	C_R $\times 10^{-3}$	C_{TS} $\times 10^{-3}$	R_T LB.	R_T/Δ LB./LT.
0	0	—	—	—	—	—	0	0
1	1.689	0.7170	2.172	0.71	0.85	3.732	520	6.03
2	3.378	1.434	1.971	"	"	3.531	1967	0.11
3	5.067	2.151	1.865	"	"	3.425	4292	0.24
4	6.756	2.868	1.795	"	"	3.355	7475	0.41
5	8.445	3.585	1.743	"	"	3.303	11498	0.64
6	10.134	4.302	1.703	"	"	3.263	16357	0.90
7	11.823	5.019	1.669	"	"	3.229	22032	1.22
8	13.512	—	—	—	—	—	28525	1.58
9	15.201	—	—	—	—	—	36222	2.00
10	16.89	—	—	—	—	—	42380	2.34
11	18.579	—	—	—	—	—	53345	2.95
12	20.268	—	—	—	—	—	62493	3.46
13	21.957	—	—	—	—	—	72723	4.02

BARGE RESISTANCE DATA

Special Note: The following pages are stamped restricted but this classification was canceled by authorization of the Ad Hoc Committee Action November 27, 1953 and signed by B.C. Taylor, security officer.

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139 HEAVY CRUISER

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>CA 139</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>21470</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>4500</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>0</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>10</u>
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	<u>1</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>4500</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>8.5</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.0</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>182495</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>324</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>109966</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>72529</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>0</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>186995</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139 HEAVY CRUISER

DATE: 2/29/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	21.5
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	1.5
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	6750
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	165319
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	70377
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	47708
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	47234
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	172069

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139 HEAVY CRUISER

DATE: 2/24/76

BY: PCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	1.2
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	5400
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	165319
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	70377
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	47708
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	47231
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	170719

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21170
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	165319
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	70377
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	47708
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	47234
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	165319

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	29.5
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	2.4
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	10800
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	2.1
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	72139
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	27491
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	17596
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	27052
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	82939

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	2.0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	9000
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	2.1
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	72137
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	27491
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	17596
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	27052
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	81139

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4500
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	2.1
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	72139
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	324
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	27491
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	17596
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	27052
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	72139

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	R_H/Δ (SEE FIG. 17)	—	2.23
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	59848
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	121079
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	1594
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	182521

TABLE - 6
CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1,300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.4
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	30058
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	77490
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (16) \times (16)$	POUNDS	7368
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	116216

TABLE - U
CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.4
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	30058
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	77490
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	7514
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	116362

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	B
15	R_H/Δ (SEE FIG. 17)	—	1.4
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	30058
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	77490
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	904
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	109752

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	32,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.58
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	15566
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	30270
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	13871
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	92207

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	32,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.58
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	15566
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	30270
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	15755
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	94091

CALCULATION OF TOWING RESISTANCE

SHIP: CA 139

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CA 139
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	21470
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4500
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	324
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	7
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	7
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	32.500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.58
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	15566
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	30270
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (14) \times (14)$	POUNDS	4177
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	82735

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST-1179 TANK LANDING SHIP

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940 *
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT	0.5
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	1970
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	9.9
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	82586
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	36703
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	45883
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	0
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	84556

* FRONTAL AREA NOT AVAILABLE SO ASSUMED TO BE SAME AS LST 1156

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179 - TANK LANDING SHIP

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>3940</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>21.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.3</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>5122</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>6.3</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>73576</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>108.14</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>23490</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>29065</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>21021</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>78698</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	1.0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	3940
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	73576
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	23490
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	27065
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	21021
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	81918

ESTIMATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>3940</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>126.34</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>0</u>
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	<u>0</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>0</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>6.3</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>73576</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	<u>109.14</u>
14	PROPELLER RESISTANCE $= R_P = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>23490</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>29065</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>21021</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>73576</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>3940</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>29.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>2.5</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>9850</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.5</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>33368</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>108.14</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>9176</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>11679</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>12513</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>43218</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/76

BY: JCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	2.0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	7680
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	2.5
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	33368
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	9176
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	11679
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	12513
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	41248

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179

DATE: 2/27/26

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>3940</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>101.8</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>-0.01</u>
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	<u>0</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>0</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.5</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>33368</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>108.14</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>9176</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>11679</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>12513</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>33368</u>

CALCULATION OF TOWING RESISTANCE

SHIP: LST-1179 TANK LANDING SHIP

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3940</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>108.14</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>18</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>9</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>0</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>10</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>0</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>3.16</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>32951</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>40412</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>1396</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>74759</u>

CALCULATION OF TOWING RESISTANCE

SHIP: LST-1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3940</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>108.14</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>18</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>9</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>4</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>21.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>1300</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>2.11</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>22002</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>25864</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>6451</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>55617</u>

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>LST-1179</u>		DATE: <u>2/27/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3940</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>108.14</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>18</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>9</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>4</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>19.82</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>30</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.20</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>1300</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>2.11</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>27002</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>25864</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>6579</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>55745</u>

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.98
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	2.11
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	22002
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	25864
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	791
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	49957

TABLE - 6
CALCULATION OF TOWING RESISTANCE

SHIP: <u>LST 1179</u>		DATE: <u>2/27/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>8432</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3940</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>108.14</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>18</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>9</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>29.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>32500</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>0.86</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>9064</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>10103</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>12145</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>69812</u>

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST-1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8432
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3740
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	38500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.86
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	9064
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	10103
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	13794
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	71461

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8432</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3940</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>108.14</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>18</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>9</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>23.98</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>90</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>0.48</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>38500</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>0.86</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>9064</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>10103</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>3852</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>61519</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25 GUIDED MISSILE FRIGATE

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0.5
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	1520
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	20.67 *
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	177349
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	238.6
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	80981
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	96368
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	0
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	178869

* USED DESTROYER CURVE

RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>CGN-25</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>8580</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>3040</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>21.5</u>
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.2</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>3648</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>12.5</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>150150</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	<u>238.6</u>
14	PROPELLER RESISTANCE $= R_P = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>51828</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>55422</u>
16	SEA STATE RESISTANCE $= R_S = (12) - (15) - (14)$	POUNDS	<u>42900</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>153799</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	1.0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	3040
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	150150
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	238.6
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	51828
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	55422
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	42900
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 2/27/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	150150
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	238.6
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	51828
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	55422
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	42900
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	150150

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	29.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	29.5
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	2.6
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	7904
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	65895
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	238.6
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	20245
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	20939
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	24711
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	73799

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	24.36
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	2.0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	6080
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	4.5
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	65895
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	238.6
14	PROPELLER RESISTANCE = $R_P = 3.394 \times (13) \times (4) \times (4)$	POUNDS	20245
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	20939
16	SEA STATE RESISTANCE = $R_S = (12) - (15) - (14)$	POUNDS	24711
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	71975

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3040
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.8
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	65895
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	238.6
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	20245
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	20939
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	24711
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	65895

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>CGN-25</u>		DATE: <u>3/1/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>CGN-25</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8580</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3040</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>238.6</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>5</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>3</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>0</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>10</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>0</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>4.75</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>50944</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>89165</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>1077</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>141186</u>

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>CGN-25</u>		DATE: <u>3/1/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>CGN-25</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8580</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3040</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>238.6</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>5</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>3</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>4</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>21.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>500</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>3.03</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>32497</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>57065</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>4977</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>95039</u>

TABLE - U
CALCULATION OF TOWING RESISTANCE

SHIP: <u>CGN-25</u>		DATE: <u>3/1/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>CGN-25</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8580</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3040</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>238.6</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>5</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>3</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>4</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>19.82</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>30</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.2</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>500</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>2.23</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>32497</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>57065</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>5076</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>95133</u>

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	8580
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	3.03
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	32497
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	57065
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	611
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	90673

TABLE - U
CALCULATION OF TOWING RESISTANCE

SHIP: <u>CGN-25</u>		DATE: <u>3/1/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>CGN-25</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>8580</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>3040</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>238.6</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>5</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>3</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>29.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>18650</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>1.24</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>13299</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>22291</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>9371</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>63611</u>

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.2
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	18650
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	1.21
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	13299
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	22291
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	10643
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	64833

CALCULATION OF TOWING RESISTANCE

SHIP: CGN-25

DATE: 3/1/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		CGN-25
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8580
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3040
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	238.6
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	5
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	3
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.48
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	18650
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	1.24
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	13299
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	22291
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	2972
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	57212

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27 Nov 53. *126 Taylor, 1st 7. T.C.*
Security Office

FINAL REPORT

JUNE 1950

PROJECT 9-57-01-04

HULL FORMS

VOL. 1

BARGE HULL FORM STUDIES

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TRANSPORTATION BOARD

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TRANSPORTATION BOARD
NEW YORK PORT OF EMBARKATION

1 June 1950

This report covers the activities of the Transportation Board in accordance with Army Regulations No. 15-30, dated 1 August 1949.

FOR THE PRESIDENT OF THE BOARD:

Robert C. Hanes

ROBERT C. HANES
Lt Colonel Inf
Secretary

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SCOPE

To examine hull forms of Transportation Corps equipment with a view toward improvement; to evaluate hull forms, by model tests and operating experience, for operating conditions of existing standard TC floating equipment, and of items selected for future use; to explore simplified hull forms in order to combine good performance with ease of production.

DISCUSSION

The development of barge hull forms to their present stage runs parallel with the development of marine operations. The Transportation Corps procured a large number of tugs, barges, and supply vessels during World War II. Many of these hulls, produced under the stress of wartime conditions, lacked the benefit of model testing and refinement of hull design. The hull-forms project was initiated to determine which of these forms were satisfactory as designed, and what improvements could be made to the poorer forms to meet operating requirements annex I.-A.

Eight existing TC barge forms were selected for model tests to determine their resistance and yaw characteristics. Two new forms designated BX 10 and BX 11 were designed and tested to replace forms of the original designs which were unsatisfactory. Additional data for comparative purposes were obtained from existing TC Board designs 7002 and 7003 (annex I.-B).

The 12 model tests covered by this report were conducted in two model-testing basins, one located at University of Michigan and the other at the Stevens Institute of Technology (annex I.-C).

Model testing and expansion of model results in this report are in conformance with the approved standards set forth by the Society of Naval Architects and Marine Engineers Hydromechanics Subcommittee (annexes I.-D and I.-E).

A comparative analysis indicates that TC barge designs range from the best to the poorest encountered in commercial practice. Generally, those barges which had long rakes flowing smoothly into the parallel middle body had the lowest relative resistance ratios. (annex I.-F).

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CONCLUSIONS

It is concluded that:

Of the barge models tested, from a towing-resistance standpoint, the following designs are unsatisfactory: 267, 336 B, 417 S, 430, and 380. The following designs are considered satisfactory: 230, 231 A, 7001, 7002, 7003, BX 10, and BX 11.

RECOMMENDATIONS

It is recommended that:

1. Results contained in this study be adopted as a guide for the development of barges for the standard TC fleet.
2. Barge designs 267, 336 B, 417 S, and 430 be declared obsolete.
3. Barge design 380 be retained in its present classification of limited standard until present stocks are exhausted.

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Designs of military barges are usually restricted to some extent, owing to stipulated dimensions of length, beam, and draft, therefore, attempts to lower resistance must be confined to proportioning and shaping the rake ends (annex I.-G).

Comparison of performance of barges with and without skegs indicates that barges equipped with properly designed skegs eliminated yaw and increased directional stability on the majority of models tested (annexes I.-H and I.-I).

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ANNEX I.

DETAILED DISCUSSION AND FINDINGS

ANNEX I.-A

Background

The development of barge hull forms to their present stage of design runs parallel with the commercial development of the inland waterways of the United States.

The first rafts of logs poled down the Mississippi gave way to wooden barges lashed to steamboats as early as 1832 (4)*, and by the late seventies, fleets of barges were in general use. With the development of the iron and steel industries the movement of coal increased in importance, and flatboats, which had been too cheap to warrant return upstream, gave way to more permanent types of barges. In the period between 1910 and 1920, steel was introduced as a hull material, but the construction methods employed produced barges which could carry only a limited cargo, owing to an excess of internal structure (6).

In the Rivers and Harbors Act of 1910, Congress authorized the Secretary of War to design and construct two experimental towboats, with a suitable complement of barges, for towing and delivering supplies along the Mississippi River and its tributaries. A board appointed by the Chief of Engineers made a thorough study of all available design and operating information, and conducted a series of model and full-scale trials of towboats and barges. The resulting published data (3) (9) constituted the first step in the improvement of barge hull forms for river transportation.

River traffic decreased sharply in 1914 and 1915. In 1918, a large portion of the river tonnage was destroyed or carried away by ice floes which filled the rivers. But in the early twenties, the Government sponsored programs for the canalization of the Ohio River, and established the Federal Barge Line. These advances were followed by projects for the improvement of the Upper Mississippi, the Missouri, the Tennessee, and the Illinois Rivers. Forerunners of the modern common-carrier barge line appeared, and the improvements discovered in the studies of 1910 to 1915 were put to use. The Corps of Engineers Towboat Board was reorganized in 1928, and a complete analysis was made of the latest practice in water transportation on the Mississippi and its tributaries (2).

*Note: Numbers in parentheses refer to technical references listed in appendix V.

During the period between 1930 and World War II, barge operators and builders began to utilize model-testing basins for the improvement of individual barges and flotillas. With the increase in industrial activities in the Gulf states, the movement up river of large cargoes steadily increased, and reductions in barge resistance became increasingly important.

Developments on the inland waterways have improved not only the performance of river barges, but canal, harbor, and seagoing barges have also shown the effects of these design changes. Barges now in existence have been especially designed for movement of a large variety of cargoes. Weatherproof covered barges, tank barges, merchandise carriers, automobile carriers, and many other types are operating commercially. The entire inland and intracoastal waterway system, with dependable river stages and efficient towboats and barges, is now an extremely important factor in the nation's transportation system. A survey of the barge forms designed, built, and operated by the Transportation Corps during World War II disclosed the fact that the design of military craft of this type lagged considerably behind the development of similar commercial equipment. Some of the existing TC barges contained construction features which are entirely outdated, and forms which have been commercially obsolete for a decade.

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ANNEX I.-B

Selection of barge hulls for testing

At the time the Transportation Corps Board barge-testing program was initiated, the selection of hull forms proved rather difficult. No standard TC fleet had been defined, and the choice of hulls which would eventually be used for this fleet could not be definitely predicted. Of the wide range of types of barges available, the Barge, Dry Cargo, Non-Propelled, Steel, 1700-Ton, 210-Foot, Design 230, and Barge, Deck Cargo, Non-Propelled, Steel, 585-Ton, 120-Foot, Design 231 A, appeared similar to representative types of successful commercial barges, and the most likely to be included in a standard TC fleet. Aside from these two designs, there seemed to be no outstandingly good hulls with the possible exception of Barge, Dry Cargo, Steel, 130-Foot, Design 267. This 130-foot cargo barge had been designed with rather complicated forward rake-end sections which, if justified by markedly lower resistance characteristics, might be considered as a future standard design.

During World War II, there was an urgent need for small harbor barges which could be shipped overseas in a compact form. Barge, Dry Cargo, Non-Propelled, Steel, 375-Ton, 112-Foot, Design 430, Knock-Down is representative of the solution evolved at that time. Although barges of this type were not entirely successful, owing to assembly difficulties, it was desired to compare the hull forms of this design and the more recent development along these lines such as Barge, Deck Cargo, Non-Propelled, Steel, Sectionalized, Nesting, 81-Foot, Design 7001.

In order to round out this series for comparative purposes, three other barges were selected: Barge, Pier, Non-Propelled, Steel, 150-Foot, Knock-Down, Design 380, a pier barge with an extremely large beam-to-length ratio; Barge, Deck Cargo, Non-Propelled, Wood, 700-Ton, 130-Foot, Design 336 B; Barge, Cargo, Steel, 112-Foot, Design 417 S, a fine-ended barge representing the so-called "simplified form."

In addition to the above hulls, contracts were issued for the design of Barge, Liquid Cargo, Non-Propelled, Steel, 9000 Bbl., 195-Foot, Design 7002, and Barge, Dry or Liquid Cargo, Non-Propelled, Steel, 500-Ton, 130-Foot, Design 7003, which both called for model tests.

Test results for designs 7002 and 7003 have been included in the analysis. Further developments to be described later indicated the need for replacement hull forms for a 112-foot and a 130-foot barge, which are included as BX 10 and BX 11.

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ANNEX I.-B (contd)

The above designs were selected for model testing in order to determine which hulls were satisfactory for further use by the Transportation Corps, and to secure basic design information which would prevent repetition of the mistakes made in barge procurement in World War II.

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ANNEX I.-C

Model-testing tanks

The twelve model tests covered by this report were carried out in two model-testing basins. Designs 267, 430, 336 B, 417, BX 10, and BX 11 were tested in the Naval Tank at the University of Michigan. Designs 7001, 7002, 7003, 230, 231 A, and 380 were tested in Tank No. 1, Experimental Towing Tank, Stevens Institute of Technology.

In the 22-by 300-foot Naval Tank, Models are towed under a carriage running the length of the basin on rails fitted along each side. A motor, which is mounted on the carriage, propels it at constant speed.

The Stevens tank No. 1 is 9 feet by 100 feet. Models are towed by a dynamometer riding on an overhead central rail. The dynamometer is propelled by means of a continuous wire running along the rail and around a motor-driven pulley. A dc motor is used to bring the model up to constant speed, and an ac synchronous motor mounted on the same shaft is cut in to tow the model at constant speed down the tank.

In the prediction of full-scale resistance values, the model results of both tanks are equally reliable. In the prediction of full-scale yaw characteristics, however, the larger size and type of carriage propulsion of the Naval Tank permits, to some extent, the quantitative evaluation of yaw, whereas the yaw results of the Stevens Tank are qualitative only. In the Naval Tank, the model can swing freely through its full amplitude of yaw throughout several cycles. The smaller dimensions of the Stevens tank No. 1 do not permit full swing of a badly yawing barge, and it is seldom that a model can complete more than $1\frac{1}{2}$ cycles. In addition, the cutting in of the synchronous motor often accelerates the model abruptly. If the model is not heading straight down the tank at this instant, the first swing is overemphasized. Thus the correction of yaw in this tank can be considered satisfactory for full-scale predictions, but uncorrected yaw cannot be measured with accuracy.

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ANNEX I.-D

Expansion of model results

The expansion of all model results covered by this report has been in conformance with the latest standards set forth by the Society of Naval Architects and Marine Engineers Hydromechanics Subcommittee, Bulletin 1-2. The Scheenherr friction formulation was used for both model and full scale. A constant addition of 0.0004 was made to the frictional-resistance coefficient for roughness. All full-scale predictions are based on immersion in salt water at 15°C (59°F).

It has been the practice at the Naval Tank, in the expansion of results of models with major appendages such as barge skegs, to add to the bare-hull results only 50 percent of the additional resistance incurred by the use of skegs. This apparent departure from Fraude's law of comparison may have some merit owing to the fact that velocity past the skegs differs from barge velocity. However, no reliable full-scale barge tests have been made to justify the use of a definite percentage of the skag resistance. Tests on Thames barges reported by Baker (5) showed close correlation between model and full-scale tests with no scale correction. All expansions covered by this report have included the full resistance of the model skag.

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ANNEX I.-E

Model tests

Contracts placed with the Naval Tank and with the Experimental Towing Tank for the eight barges originally selected (designs 7001, 231 A, 230, 380, 267, 430, 417 S, and 336 B) called for resistance tests and yaw tests at three displacements for each barge. Alterations were to be made to each hull to lower resistance and reduce yaw, and the altered models were to be similarly tested. The basic resistance and yaw tests were completed in accordance with these requirements, and the plotted results, together with the rake profile and body plans of these vessels are shown in figures 1A through 8C inclusive of appendix III. A description of the alterations made and discussion of the performance of each form follow:

Design 7001 (fig 1A, app III.)*

This 81-foot barge was designed specifically for sectionalization and nesting of the individual sections. The hull form has necessarily been designed to meet these requirements. However, in spite of the restrictions to shaping of the hull, the resistance of this barge is quite satisfactory (fig 1B). When towed behind a single line, a distinct tendency to yaw was demonstrated. This was overcome to some extent by towing with a bridle. Because of the design restrictions, no alterations were attempted to improve resistance or yaw characteristics.

Design 231 A (fig 2A)

For a simply shaped, symmetrically ended hull form, this 120-foot barge showed exceptionally low resistance characteristics (fig 2B). Three alternate bow-and-stern combinations with considerably more shape than the original rake ends failed to reduce the resistance. Rounding off of the bilges to a 12-inch radius showed no improvement over the original 1-inch radius. The single centerline skeg, however, proved to be entirely ineffective in preventing yaw, which was uncontrollable in the model basin. The substitution of two outboard plate skegs with prisms at the after ends (fig 2C) was required to insure directional stability. The total resistance was thus considerably increased (fig 2D).

Design 230 (fig 3A)

This 210-foot cargo barge had the lowest resistance characteristics of all barges tested (fig 3B) owing to the ship-form bow. The yaw was satisfactorily corrected by the Ingalls, a pyramid-type skeg, but with a prohibitive increase in resistance. By the substitution of plate skegs with prisms (fig 3C) the yaw was corrected with a definitely lower resistance penalty (fig 3D).

*Note: All figures (except figure 1) referred to in this report are shown in appendix III.

ANNEX I.-B (contd)

Design 380 (fig 4A)

This 150-foot pier barge has a fairly high resistance (fig 4B), which could be reduced 15 to 25 percent by shaping of the forward rake-end bilges. However, as this barge would seldom be used for actual towing, the reduction in resistance would not justify the added construction cost. In the even-keel condition, this barge had an uncontrollable yaw which could not be reduced, even with the addition of three plate skegs with prisms. Additional tests proved that directional stability could be restored by operating with a bridle, and with approximately 1 foot of trim. Little increase in resistance was indicated when operating under these conditions.

Design 267 (fig 5A)

This 130-foot steel barge has favorable resistance characteristics which have been obtained by a complicated bow design. From a resistance standpoint the vessel is satisfactory, but the additional cost of construction required appears unwarranted. The curves of total resistance are given in figure 5B, and curves of yaw amplitude in figure 5C. The barge as designed is directionally unstable.

Design 430 (fig 6A)

The knock-down principle employed in the construction of this 112-foot steel barge necessitated to some extent the abrupt form contours. The resistance penalty of this barge (fig 6B) was tremendous, its resistance being the highest of all barges tested. The directional stability without the use of skegs was exceptional (fig 6C).

Design 417 S (fig 7A)

This 112-foot steel barge of the "straight-element" form also showed a high resistance for the amount of cargo carried (fig 7B). The vessel was directionally unstable (fig 7C); hand-operated rudders of the type used on this barge are entirely ineffective in overcoming yaw.

Design 336 B (fig 8A)

This 130-foot wooden lighter barge had a very high resistance (fig 8B), owing chiefly to the paneled construction used on the sides. The vessel could not be considered directionally stable, but the yaw amplitude was not too great (fig 8C).

Design BX 10 (fig 11A)

Because of the unsatisfactory performance of designs 430 and 417 S, it was felt that there would be no advantage in altering these hulls. Professor L. A. Baier of the University of Michigan agreed to submit a new "straight-element form" design, embodying in general the over-all dimensions and tonnages of these two barges. This form, designated BX 10,

was tested with and without skegs (figs 11B, 11C), and showed exceptionally good performance. Although the skegs increased the resistance considerable, yaw was completely eliminated.

Design BX 11 (fig 12A)

Owing to the high construction cost expected for design 267 and the high resistance of design 336 B, a "straight-element form" replacement was designed by Professor Baier. This barge also had a low resistance, and complete directional stability was attained (figs 12B, 12C).

Design 7002 (fig 9A)

This 196-foot steel barge was recently designed by the TC Board as a liquid carrier. The easy forward rake and the forming of the deck line forward and aft give exceptionally low resistance. The model testing of this barge was accomplished under its design contract, and the data obtained cover only one deep-water test which can be compared with other barge tests (fig 9B). The barge was directionally unstable when tested with designed skegs, and the substitution of the skeg shown in figure 9C is recommended. The additional resistance incurred by this skeg would probably lie somewhere between the values for designs 230 and 231 A (fig 19).

Design 7003 (fig 10A)

This 130-foot oil barge was also designed recently by the TC Board. The only deep-water test which can be compared with the other barges (fig 10B) was conducted with yaw corrected by the skegs shown in figure 10C, which are recommended as replacements for the skegs originally designed. The test indicated that this form was one of the best of the group.

ANNEX I.-F

Comparison of resistance results

Comparative results of the model tests are shown in the graph on the next page. Design 7001 was left unchanged. On design 380 the yaw was corrected by trimming by the stern, and without use of skegs. No attempt was made to correct design 7002 because the yaw was small, and experience had proved that when yaws are of very small amplitude in tank tests they are not apparent in the full-size vessel. Design 7003 was towed with skegs only, and no base hull data are available. Skegs of designs 231 A and 230 were altered to reduce yawing with a minimum increase in resistance. Design 267 has good resistance characteristics, but lacks directional stability. Designs 417 S, 430, and 336 B are considered entirely unsatisfactory, and should serve as an example of types to be avoided in the future. Designs EX 10 and EX 11 offer low resistance together with low initial construction costs, owing to simplification of form.

It is recommended that the conclusions of this report be adopted as guides for the design and procurement of future barges for Transportation Corps use.

Resistance results for all barges at load displacement in deep water are compared in figures 13, 14, 15, and 16. The values have been reduced to a comparative basis by plotting against the Froude number. This has been used in preference to the normally accepted speed-length ratio because of the confusion often occurring in rating barges in knots or in statute miles per hour. In figures 13 and 14 the total resistance has been expressed in pounds per pound displacement rather than pounds per ton, to permit use with either long or short displacement tons. Use has been made (figs 15, 16) of the "volumetric" residual resistance coefficient to permit dimensionless comparison of residual resistance on a basis which indicates the carrying capacity of the barge.

A comparison of the curves of figure 13 with model-test results for 14 barges given by Baier (1) shows that design 230 has a lower resistance than any of them. Designs EX 10 and 7002 are on a par with the best of the barges shown. Designs EX 11, 231 A, 267, and 7002 are better than average, and designs 380, 7001, 336 B, and 417 S graduate throughout the range. Design 430 is quite similar to the poorest of the 14 barges tested. This indicates, therefore, that TC barge designs range from the best to the worst encountered in commercial practice.

Basic barge performance can best be analyzed by reference to the curves of figure 15. Here the comparative bare-hull form resistances are clearly shown. The averages of these values between Froude numbers of 0.10 and 0.20 are shown in the graph (fig 1) which serves as a rating index for this group of barges.

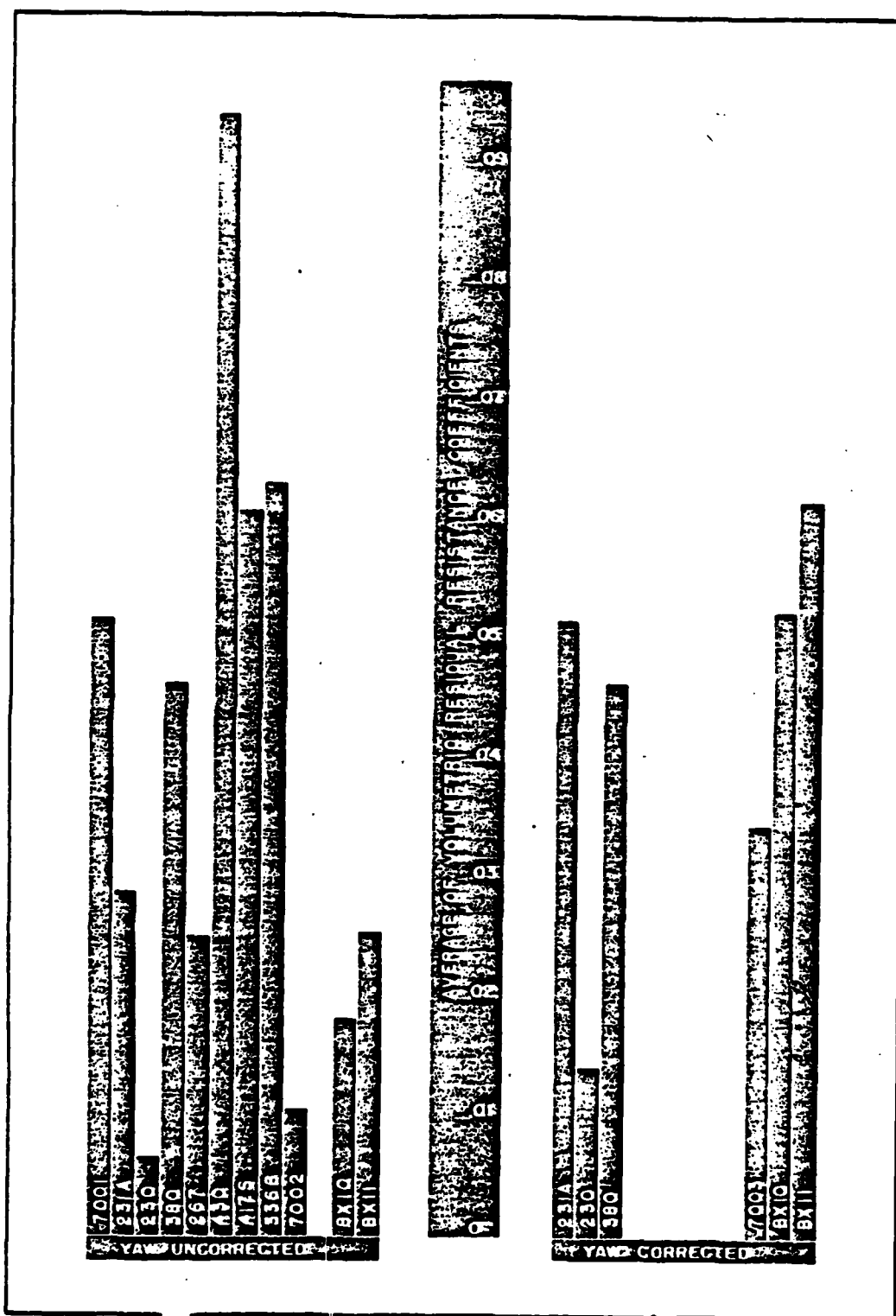


Figure 1. Comparison of specific volumetric residual resistances of barges tested.

ANNEX I.-F (contd)

Reference to the proportional sectional-area curves (fig 17) gives a visual description of the basic cause of the high resistance of some of these barges. These curves have been staggered for clarity. The ordinates represent the ratio of section area to midship section area for each barge. The abscissas represent the ratio of rake-end length (on water-line) of each barge to the maximum rake-end length of the barges tested (design 230 forebody; design BX 11 afterbody).

The high resistances of designs 430 and 417 S can be attributed directly to the sharp break in the sectional-area curve where the rake-end meets the middlebody. The resistance of design 430 is greater, owing to the shorter rake length.

The short rake lengths of designs 380, 7001, and 336 B raise the resistances, but the fair curvature of the sectional-area curves gives an indication of good form. Design 336 B has a higher resistance, as the paneling of the parallel sides causes severe eddying. The easy sweep of the sectional-area curves of designs 231 A and 267 combined with fairly long rake ends give good forms with reasonably low resistance. From the appearance of the relative resistances, the change in curvature of the sectional-area curve at the bow, giving a smaller entrance angle combined with greater rake length, is conducive to very low resistance values as exemplified by designs 230, 7002, 7003, BX 10, and BX 11. The differences in average specific resistance of these designs can be caused by waterline shape, length-to-beam ratio, and beam-to-draft ratio as listed in table II. For the four bare-hull tests available, the specific resistances vary almost linearly with the length-to-draft ratio, but there have not been sufficient tests to accept this as a general statement.

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ANNEX I.-G

Discussion of barge-form design

Certain design considerations are apparent from the comparison of the barge-model tests completed under this project. These may be listed as follows:

a. The shape of the sectional-area curve is a definite factor in determining barge resistance. In general a small slope of the curve at entrance combined with a low prismatic coefficient and fair curvature throughout tend to lower resistance.

b. The length of the rake ends is a controlling factor. Normally, the longer the rake end, the lower the resistance. However, where resistance is compared with displacement tonnage, a certain optimum length is indicated. A series of tests at the University of Michigan established the optimum length of the forward rake end as 25 percent of the length over-all. It was also found that the after rake end could be of the same form as the forward rake, but with the after end cut off to reduce the after rake length to 80 percent of the forward rake length. This gave the lowest values of resistance per ton of displacement.

c. The slope and shape of the forward rake-end keel line have often been considered quite critical. Tests by Sadler (3), Baier (1), and Hay (7) (8) demonstrated wide variations in resistances with various slopes and shapes. However, the tests conducted on modifications of design 231 A, and the low resistances of designs 267 and 230 indicate that these variations were due more to changes in the sectional-area curve than to changes in the rake profile. Three sets of bow-and-stern rake ends were constructed for design 231 A. These ends had lateral-area coefficients of 0.67, 0.75, and 0.83, respectively, with a parabolic profile. The sectional-area curve (and therefore entrance and run prismatic coefficients) were identical for all three sets. The resistance results obtained by any combination of these forms was identical. It is therefore believed that the shape and slope of the rake profile are important for resistance only insofar as they affect the sectional-area curve. For a fairly full formed rake end, a rake angle of 30 degrees seems to give the most satisfactory sectional-area curve.

d. The ratios of length-to-beam and beam-to-draft have a decided effect on resistance. Designs BX 10 and BX 11, which have otherwise nearly identical coefficients, show a 30 percent difference in residual resistance. In general, the resistance decreases with increasing values of these ratios.

e. Any unnecessary eddy-making appendages such as the paneling on design 336 B are to be avoided.

f. Good barge forms can be obtained without complicated construction features.

ANNEX I.-G (contd)

g. Deadrise and a large bilge radius are important factors in allow-water operation (1), but may be less significant for deep-water operation.

The dimensions of length, beam, and draft are usually stipulated in the design of military barges, which restricts the designer to some extent. In these cases, attempts to lower resistance must be confined to the proportioning and shaping of rake-ends. He is also restricted to shapes which lend themselves to simple and inexpensive construction. In dealing with a rounded bilge form, the use of a constant radius simplifies fitting by reducing the rolling or furnacing operation to a single pair of strakes. Figure 18A shows two types of barges which employ this principle. The rake end profiles are identical, but in one barge a good sectional-area curve has been obtained by tapering in the sides to the headlog. Where a large deck area is required, the sectional-area curve can be retained by varying the deadrise as shown in the second body plan. The fore and after rakes are symmetrical, with 15 percent cut from the rake aft. This feature has the added advantage that if flotilla operation is desired, the barges may be secured stern to stern.

As a third alternative type, the "straight element" form for barge rake ends is employed in figure 18B. Considerable experimentation was done along these lines at the University of Michigan for the Ingalls Corporation, and the proportions shown represent the optimum values found. This form is adaptable to the use of developed plates between the upper and lower chine. The Ingalls "Patented Bow" uses the developed surface of a cone with the apex at point A to form this plate. A cylindrical development is also possible, or straight sections may be used as shown.

By reference to the three suggested standards and principles set forth above, it should be possible for a designer with relatively little barge experience to design a good hull form, easily constructed, and with low-resistance characteristics.

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ANNEX I.-H

Comparison of skeg performance

Of the 12 barges tested, 8 were originally fitted with some type of device expected to insure directional stability. Design 231 A had a single, straight-sided centerline skeg. Design 230 had two Ingalls patented pyramid-type skegs. Designs 267, 7002, and 7003 had pairs of straight-sided skegs. Design 417 S had a centerline rudder, and designs EX 10 and EX 11 had pairs of offset Dravo-type skegs. Of the eight tested, only those on designs 230, EX 10, and EX 11 actually eliminated yaw.

Types of skegs recommended by the Experimental Towing Tank were fitted to designs 231 A, 230 380, and 7003. The yaw was eliminated on all but design 380, which required the combination of trim and a bridle to attain stability. The relative resistances of the skegs which actually corrected yaw are shown in figure 19.

From these curves it appears that the yaw-correcting skegs of lowest resistance are of the Experimental Towing Tank type, consisting of plate skegs with vertical, triangular prisms fitted to the after ends.

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ANNEX I.-I

Discussion of directional stability

Directional stability, or the ability of a barge to follow a straight course behind a towing vessel, is an extremely important factor in the operations of tugs and barges. A yawing barge is a danger to navigation and to the towing vessel. The sheering of a barge in a turn has been known to capsize the towing vessel. It also greatly reduces the efficiency of towing operation.

When an external force such as a wave throws a barge off course, a new transverse resistance force is added. If the moment of this force about the center of gravity opposes and exceeds the restoring moment of the force exerted by the towline, the barge will be directionally unstable. The stability may be restored by several methods:

The use of a towing bridle increases the moment arm of the restoring force.

The use of skegs or a rudder decreases the moment arm of the transverse resistance by moving aft the center of lateral resistance. (Rudders have been unsuccessful, as they do not exert a great enough force unless the yaw is anticipated by the helmsman).

The trimming of the barge moves the center of lateral resistance aft, and by relocation of the center of gravity, increases the moment arm of the restoring force.

Fining the forward lines to reduce transverse resistance, or filling out the after lines, tends to move the center of lateral resistance aft.

Studies at the University of Michigan (10) showed that a bridle length of 1-1/2 barge beams was the most effective in overcoming yaw. A series of tests on skegs carried out at the University of Michigan in 1938 for the Dravo Corporation (1) resulted in the design of a very efficient skeg; this type was used on designs BX 10 and BX 11. However, barge tests of project 9-57-01-04 indicate that a skeg of the type developed by the Stevens Experimental Towing Tank corrects yaw with less resistance penalty than the Dravo or the Ingalls skegs. This type of skeg (fig 20) is recommended as a standard for future TC designs until further studies can be made. Consideration should also be given to retractable skegs for TC barges operating in both rivers and harbors.

Investigations of the relationship between directional stability and form design have been limited mainly to ship-form vessels propelled and controlled from the stern. The same techniques could be applied to barge-hull forms to give very worthwhile information on this subject. The great

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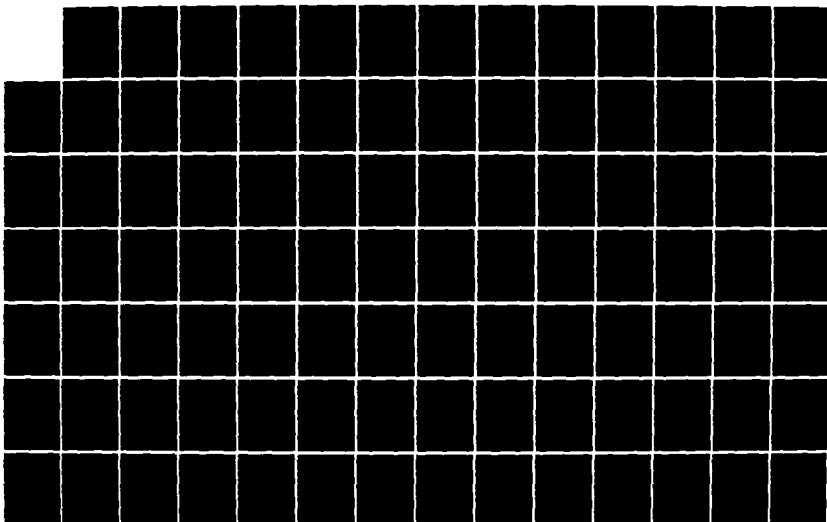
DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE
DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U)
ROSENBLATT (M) AND SON INC NEW YORK APR 76

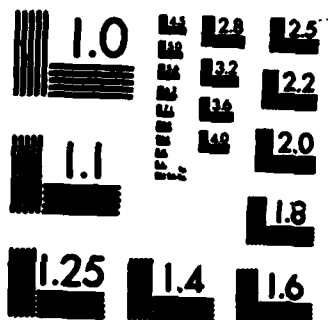
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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ANNEX I.-I (contd)

improvements in barge resistance effected in the last 10 years have been nullified to a large extent by the necessity of adding high-resistance skegs. This phase of the barge-design problem has been sadly neglected, and further studies by the Transportation Board along these lines are strongly advocated.

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CONCLUSIONS

It is concluded that:

1. Barge designs 417 S, 430, and 336 S are entirely unsatisfactory.
2. Design 330 has satisfactory resistance characteristics for a special-purpose barge. Yaw can be controlled by the use of trim and bridle.
3. Design 7001 is a distinct improvement over design 430, and fulfills satisfactorily the requirement for a sectionalized barge.
4. Design 231 A can be improved for shallow-water operation by increase of the bilge radius to 18 inches. Yaw can be eliminated by substitution of the revised skegs shown in figure 30.
5. Design 230 has extremely low resistance which can be further reduced by substitution of the skegs shown in figure 30.
6. Design 267 has reasonably low resistance, but the complicated bow formation indicates high construction cost. Yaw of barge as now designed is excessive.
7. Designs 7002 and 7003 have excellent resistance characteristics. Directional stability can be increased by substitution of the skegs shown in figures 30 and 100.
8. Designs HK 10 and HK 11 are satisfactory replacements for designs 417 S, 430, 336 S, and 267.
9. Recent TC Board barge designs compare favorably with the most recent commercial designs of the same type barges.
10. Retractable skegs are practicable for TC barges operating both in rivers and harbors.
11. A great deal of study is required to determine and correct the directional instability of barges.

RECOMMENDATIONS

It is recommended that:

1. Designs 417 S, 336 S, 430, and 267 be classified obsolete.
2. Skeg revisions of the type shown be incorporated on designs 231 A,

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230, 7002, and 7003.

3. The bilge radius on design 231 A be increased to 12 inches.
4. The full-scale resistance data on all operating barges covered by this report be published for the use of the operating services.
5. The line drawings of designs BK 10 and BK 11 be retained, to fulfill future requirements for a 112-foot or a 120-foot barge.
6. Consideration be given to retractable shegs for use on barges operating both in rivers and harbors.
7. The types of forms shown in figures 18A and 18B and the sheg shown in figure 20 be used as guides in future barge designs.

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APPENDICES

APPENDIX	I.	AUTHORITY
	II.	LIST OF SYMBOLS AND COEFFICIENTS
	III.	HULL FORMS, SKIDS, AND RESISTANCE CURVES
	IV.	HULL FORM DATA AND RESISTANCE TABLES
	V.	REFERENCES

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APPENDIX I

ARMY SERVICE FORCES
Office of the Chief of Transportation
Washington 25, D. C.

SPDS-6

2 May 1946

MEMORANDUM FOR THE COMMANDING GENERAL, ARMY SERVICE FORCES
Attention: Chief, Research and Development Branch

SUBJECT: Research and Development Project 57 M-38, Ball Forms;
approval requested.

1. The Transportation Corps Technical Committee recommends that Research and Development Project 57 M-38, Ball Forms, be approved.

2. The recommendations contained in the inclosed subcommittee report were approved at Transportation Corps Technical Committee meeting held 1 May 1946. This paper is forwarded for formal approval.

FOR THE CHIEF OF TRANSPORTATION:

2 Incl.

1. Report 4/22/46 (quad)
2. Concurrence sheet

(signed)

GAIL E. GRACE

Colonel, TC

Chief, Research & Development Branch

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APPENDIX I (contd.)

**SUBJECT: Research and Development Project 57 M-38, Ball Forms,
approval requested.**

SEROS (2 May 1946)

1st Indorsement

Headquarters, Army Service Forces, Washington, D. C., 15 May 1946.

**To: Chief of Transportation
Attention: Research and Development Division**

- 1. Project 57 M-38, Ball Forms, is approved.**
- 2. The recommendations contained in Paragraphs 3b. and 3c., attached subcommittee report, are approved.**
- 3. The expenditure of funds in the amount of \$30,000, from funds available to the Chief of Transportation, is authorized.**
- 4. Priority Classification 3-A is assigned to this project.**

FOR THE COMMANDING GENERAL:

(signed)

2 Incls:

- 1 - quad & trip w/d**
- 2 - n/c**

**M. H. IRVINE
Colonel, General Staff Corps
Acting Chief, Research & Development Branch**

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Coefficients

- L_R/L Ratio, length of run/length
- B_R/H Ratio, beam/draft
- $S/\nabla^{2/3}$ Ratio, wetted area/(volume of displacement)^{2/3}
- S/L^2 Ratio, wetted area/length²
- C_b Coefficient, block. The volume of the underwater body of the vessel divided by the volume of a rectangular solid having the same dimensions, L , B_R , H , as the vessel.
- C_p Coefficient, prismatic or longitudinal. The volume of the underwater body of the vessel divided by the volume of a prism having the length L and the cross-section of area A_x .
- C_x Coefficient, maximum section. The area A_x of the maximum vertical transverse section of the underwater body of the vessel divided by the area of a rectangle having the dimensions B_R and H .
- C_w Coefficient, waterplane. The area A_w of the waterline plane, WL divided by the area of a rectangle having the dimensions L and B_R .
- C_{pv} Coefficient, prismatic, vertical. The volume of the underwater body of the vessel divided by the volume of a vertical prism having a horizontal section equal to the waterplane area A_w and a height equal to the draft H ; in terms of the other coefficients:
- $$C_{pv} = \frac{(C_p)(C_x)}{C_b}$$
- C_{pe} Coefficient, prismatic, entrance. The volume of the entrance of the vessel divided by the volume of a prism having the length of the entrance and the same cross-section area A_x as that of the maximum section of the vessel.

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APPENDIX II (contd)

Coefficients

- C_{pr} Coefficient, prismatic, run. The volume of the run of the vessel divided by the volume of a prism having the length of the run and the same cross-section area A_x as that of the maximum section of the vessel.
- C_{pv} Coefficient, prismatic, vertical, entrance. The volume of the entrance of the vessel divided by the volume of a vertical prism having a horizontal section equal to the waterplane area of the entrance and a height equal to the draft at midlength of the vessel.
- C_{prv} Coefficient, prismatic, vertical, run. The volume of the run of the vessel divided by the volume of a vertical prism having a horizontal section equal to waterplane area of the run and a height equal to the draft at midlength of the vessel.
- C_{pt} Coefficient, prismatic, transverse, entrance. The volume of the entrance of the vessel divided by the volume of a transverse prism having a vertical section equal to the lateral area of the entrance and a transverse dimension equal to the beam of the vessel.
- C_{prt} Coefficient, prismatic, transverse, run. The volume of the run of the vessel, divided by the volume of a transverse prism having a vertical section equal to the lateral area of the run and a transverse dimension equal to the beam of the vessel.
- v Speed of vessel in feet per second
- V Speed of vessel in knots
- g Acceleration of gravity in feet per second²
- ρ Mass density in pounds seconds² per foot³
- R Resistance in pounds
- R_0 Residual resistance in pounds

TABLE 1.

Tabulation of Total Resistance of Surge
- as designed - Deep Water

Design	220			221 A			7001			800		
Δ Wave 10 Feet	1,000	1,700	2,000	240.0	300.0	700.0	00.0	00.0	100.0	200	700	1,000
	0.00	0.00	10.00	2.00	0.00	0.00	1.00	2.00	0.00	1.00	0.00	7.00
$\frac{1}{2}$	Total resistance in pounds											
0	1,000	2,000	2,000	700	1,000	1,000	200	070	000	1,000	2,100	2,000
0	2,000	3,000	3,000	1,000	1,000	2,000	000	030	1,000	2,100	3,100	3,000
0	3,000	4,000	7,000	1,000	2,000	4,000	000	1,000	2,100	3,000	4,000	0,000
7	0,000	7,000	10,000	2,000	2,000	0,000	1,000	2,000	2,100	0,000	0,000	12,000
0	7,000	10,000	10,000	2,000	0,000	0,000	2,000	0,000	0,000	0,000	0,000	17,000
0	10,000	14,000		0,000	0,000	10,000	2,000	0,000	7,000	0,000	12,000	
10	12,000			0,000	10,000		0,000	7,000		10,000		

Design	000			207			027 B			200 B		
Δ Wave 10 Feet	201.0	000.0	001.0	070.7	000.0	000.7	000.0	027.0	070.0	000.0	700.0	1100.0
	0.00	0.00	7.00	0.00	7.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
$\frac{1}{2}$	Total resistance in pounds											
0	2,100	2,000	2,000	1,000	1,000	1,000	700	1,000	1,000	1,000	2,000	0,000
0	2,000	0,000	0,000	1,000	2,000	2,000	1,000	2,000	0,000	2,000	0,000	0,000
0	0,000	0,000	0,000	2,000	2,000	2,000	1,000	2,000	0,000	2,000	0,000	2,000
7	0,000	0,000		2,000	0,000	0,000	2,000	0,000	0,000	0,000	0,000	10,000
0	0,000	10,000		0,000	7,000		2,000	0,000	0,000	0,000	10,000	
0	10,000			0,000	10,000		0,000	0,000	10,000	11,000		
10	10,000			10,000			7,000	11,000		10,000		

Design	7002			7000			02 10			02 11		
Δ Wave 10 Feet		0.00			0.00		007.0	070.0	000.0	070.0	700.0	000.0
							2.00	0.00	7.00	0.00	7.00	0.00
$\frac{1}{2}$	Total resistance in pounds											
0		2,000			1,000		900	1,000	2,000	1,000	2,000	2,000
0		2,000			2,000		1,000	2,000	2,000	2,000	0,000	0,000
0		0,000			0,000		2,000	2,000	2,100	2,000	0,000	0,000
7		0,000			0,000		0,000	0,100	7,000	0,000	0,000	11,000
0		0,000					0,000	7,000	0,000	7,000	11,000	14,000
0		0,000					0,000	10,000	10,000	10,000	10,000	
10							0,000			10,000		

TABLE 11.

Ball-Pore Data and Coefficients

Design	7001	231 A	230	230	237	420	417 B	270 B	7002	7003	22 10	22 11
1	77.2	110.2	200.0	120.0	120.1	112.7	100.7	100.0	100.0	120.0	120.0	120.2
2	10.0	22.0	00.0	00.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
3	0.0	0.0	0.0	7.0	0.0	7.0	0.0	0.0	0.0	0.0	7.0	0.0
4	5.127	26.730	00.210	10.000	20.734	20.700	11.000	20.070	00.210	27.107	10.200	10.100
5	1.002	1.010	11.120	10.000	0.200	0.070	2.000	0.200	0.207	0.000	0.200	0.201
6	3.070	3.202	0.200	2.000	0.200	2.007	0.070	2.200	1.010	1.077	1.000	1.000
7	1.207	0.120	0.000	7.100	1.220	0.127	0.000	0.200	0.100	0.120	0.200	1.000
8	0.000	0.000	7.200	7.207	0.207	0.000	0.200	7.100	0.000	0.010	0.000	0.007
9	2.107	0.000	0.210	0.007	0.070	0.000	0.200	0.007	0.070	0.000	0.207	0.000
10	0.000	2.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.000	0.000
11	0.010	1.000	0.000	0.000	0.001	0.000	0.000	2.000	0.000	0.000	2.000	0.000
12	0.000	0.000	0.070	0.000	0.000	1.000	0.070	1.000	0.000	0.000	0.000	0.000
13	1.200	0.200	0.010	1.200	0.000	1.200	0.000	1.000	0.000	0.000	0.000	0.000
14	2.100	2.100	0.007	0.000	0.000	2.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.010	0.010	2.070	0.070	0.000	2.000	0.010	0.000	0.070	0.000	0.000	0.000
16	2.010	0.000	0.070	0.070	0.000	0.000	0.010	0.000	0.000	0.000	2.000	0.000
17	2.000	0.000	0.070	0.070	0.007	0.000	0.000	2.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	2.001	1.000	2.000	1.000	0.000	0.000	0.000	0.000
20	2.000	0.000	0.007	0.000	2.002	1.000	0.000	1.000	0.007	0.000	0.000	0.000
21	2.110	0.210	0.200	0.000	0.100	0.100	0.100	0.100	0.100	0.000	0.200	0.200
22	2.110	0.210	0.170	0.000	0.107	0.100	0.100	0.100	0.100	0.000	0.210	0.200

TABLE III.

Sectional-Area Curves

Position Station	7.00	221.4	220	200	207	420	417.8	224.8	7003	7003	EX 10	EX 11
0	0	0	0	0.200	0	0.007	0	0	0	0	0	0
1	0.142	0.220	0.077	0.443	0.276	0.181	0.047	0.207	0.106	0.137	0.100	0.106
2	0.270	0.452	0.214	0.670	0.406	0.246	0.106	0.440	0.226	0.272	0.200	0.207
3	0.401	0.613	0.325	0.890	0.601	0.340	0.173	0.606	0.302	0.410	0.400	0.437
4	0.530	0.763	0.70	0.771	0.700	0.434	0.236	0.713	0.514	0.544	0.646	0.610
5	0.671	0.966	0.822	0.643	0.944	0.520	0.300	0.900	0.626	0.607	0.910	0.770
6	0.775	1.000	0.900	0.900	0.901	0.623	0.400	0.802	0.743	0.773	0.900	0.800
7	0.970	0.970	0.940	0.943	0.945	0.717	0.574	0.904	0.826	0.804	0.903	0.900
8	0.963	0.900	0.900	0.974	0.907	0.811	0.704	0.971	0.900	0.907	0.977	0.902
9	0.907	0.900	0.907	0.900	0.904	0.900	0.946	0.903	0.902	0.973	0.902	0.906
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
11	0.907	0.900	0.900	0.900	0.900	0.900	0.946	0.903	0.973	0.973	0.901	0.906
12	0.900	0.900	0.900	0.974	0.970	0.911	0.704	0.971	0.907	0.927	0.973	0.903
13	0.970	0.970	0.923	0.943	0.946	0.717	0.874	0.904	0.900	0.904	0.900	0.907
14	0.775	0.900	0.900	0.900	0.900	0.623	0.400	0.902	0.700	0.773	0.900	0.900
15	0.671	0.900	0.702	0.643	0.910	0.520	0.300	0.900	0.600	0.607	0.900	0.903
16	0.530	0.700	0.670	0.771	0.600	0.434	0.236	0.713	0.500	0.544	0.704	0.600
17	0.401	0.510	0.501	0.600	0.601	0.340	0.173	0.606	0.300	0.410	0.500	0.493
18	0.270	0.402	0.300	0.670	0.370	0.246	0.106	0.440	0.242	0.272	0.300	0.200
19	0.142	0.230	0.410	0.443	0.100	0.181	0.047	0.207	0.110	0.137	0.222	0.100
20	0	0	0	0.200	0	0.007	0	0	0	0	0.007	0.100

TABLE IV.

Resistance of Barges in Pounds per Pound Displacement
Yaw Uncorrected

$\frac{V}{V_T}$	Values of $R/D \times 10^3$										
	7002	231 A	230	390	267	417 S	430	336 B	7032	EX 10	EX 11
0.08		0.534	0.345	0.940						0.440	0.479
0.10	1.575	0.510	0.535	1.715	0.907	1.720	2.209	1.543	0.615	0.678	0.740
0.12	2.335	1.160	0.785	1.715	1.132	2.452	3.172	2.145	0.910	0.967	1.060
0.14	2.870	1.575	1.085	2.365	1.515	3.417	4.354	2.961	1.255	1.307	1.449
0.16	3.445	2.045	1.465	3.245	1.995	4.515	5.795	3.495	1.690	1.727	1.941
0.18	4.960	2.640	1.890	4.440	2.722	6.044	7.500	5.016	2.310	2.254	2.559
0.20	6.260	3.670	2.715	6.000	4.150	7.715		6.325	3.390	3.008	3.333
0.22	7.760	4.680	3.770			9.590				4.082	4.345
0.24	9.400	6.010				12.082				5.444	
0.26	12.636	7.975				15.000					
0.28	16.445										
0.30	20.270										

TABLE V.

Resistance of Barges in Pounds per Pound Displacement
Yaw Corrected

$\frac{V}{V_T}$	Values of $R/D \times 10^3$					
	231 A	230	390	7032	EX 10	EX 11
0.08	0.535	0.345	0.940	0.70	0.925	0.975
0.10	1.310	0.535	1.777	1.305	1.440	1.515
0.12	1.997	1.145	1.725	1.417	2.052	2.172
0.14	2.507	1.545	2.365	1.975	2.795	2.945
0.16	3.250	2.325	3.290	2.547	3.635	3.445
0.18	4.145	2.735	4.425	3.255	4.684	4.985
0.20	5.135	3.655	5.660	4.130	5.795	6.095
0.22	6.725	5.785			7.105	7.421
0.24					7.657	

Table VI.

Volometric Residual Resistance Coefficients
Tau Uncorrected

$\frac{\tau}{\sigma}$	Values of $\frac{R}{\sqrt{V}} \times 10^3$										
	7001	231 A	230	200	207	420	417 S	206 S	7002	24 10	2K 11
0.00		29.96	4.00	66.36						17.16	23.64
0.10	66.46	29.23	5.23	62.78	23.42	93.21	66.94	62.00	7.31	17.15	23.62
0.12	61.85	27.87	4.88	63.87	24.74	93.39	66.61	61.77	6.33	17.10	23.74
0.14	61.42	27.41	5.79	61.90	22.42	91.93	66.67	61.83	9.16	17.23	24.19
0.16	61.30	27.16	6.08	60.70	22.86	90.62	61.33	62.67	9.00	17.37	25.43
0.18	61.76	29.78	6.70	60.70	26.14	94.90	64.70	64.34	12.27	19.29	27.32
0.20	62.70	32.12	11.73	57.39	3.39	140.76	67.31	66.46	17.79	22.06	29.72
0.22	66.30	36.39	13.20				70.62			26.67	31.30
0.24	66.30	46.00					74.72			31.00	36.61
0.26	66.34	46.62									
0.28	70.63										
0.30	86.06										
Av. 0.10 to 0.20	61.99	29.96	6.75	66.34	23.21	93.94	66.91	63.36	10.74	19.46	23.67

Table VII.

Volometric Residual Resistance Coefficients
Tau Corrected

$\frac{\tau}{\sigma}$	Values of $\frac{R}{\sqrt{V}} \times 10^3$					
	231 A	230	200	7003	24 10	2K 11
0.00	61.99	10.00	66.36	37.43	61.00	61.33
0.10	61.30	11.60	62.78	36.63	61.90	61.39
0.12	60.96	12.61	63.87	33.41	61.96	61.36
0.14	60.93	13.71	61.90	32.40	61.79	61.34
0.16	61.42	14.60	60.70	34.79	62.21	61.32
0.18	62.36	15.64	60.70	36.41	62.72	62.70
0.20	63.61	17.40	57.39	37.69	63.57	62.33
0.22	66.32	20.12			64.60	62.06
0.24					66.46	
Av. 0.10 to 0.20	61.96	14.24	66.34	34.72	62.39	61.74

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APPENDIX III

Hull Forms, Skogs, and Resistance Curves

Figure

Title

1A	Design 7001. Lines
1B	Design 7001. Curves of total resistance
2A	Design 231 A. Lines
2B	Design 231 A. Curves of total resistance
2C	Design 231 A. Skog revision
2D	Design 231 A. Curves of total resistance with revised skogs
3A	Design 230. Lines
3B	Design 230. Curves of total resistance
3C	Design 230. Skog revision
3D	Design 230. Curves of total resistance with revised skogs
4A	Design 300. Lines
4B	Design 300. Curves of total resistance
5A	Design 267. Lines
5B	Design 267. Curves of total resistance
5C	Design 267. Curves of yaw amplitude
6A	Design 430. Lines
6B	Design 430. Curves of total resistance
6C	Design 430. Curves of yaw amplitude
7A	Design 417 B. Lines
7B	Design 417 B. Curves of total resistance
7C	Design 417 B. Curves of yaw amplitude
8A	Design 334 B. Lines
8B	Design 334 B. Curves of total resistance
8C	Design 334 B. Curves of yaw amplitude
9A	Design 7002. Lines
9B	Design 7002. Curves of total resistance
9C	Design 7002. Skog revision
10A	Design 7003. Lines
10B	Design 7003. Curves of total resistance
10C	Design 7003. Skog revision
11A	Design XI 10. Lines
11B	Design XI 10. Bare-hull curves of total resistance
11C	Design XI 10. With skogs. Curves of total resistance
12A	Design XI 11. Lines
12B	Design XI 11. Bare-hull. Curves of total resistance
12C	Design XI 11. With skogs. Curves of total resistance
13	Comparative curves of large total resistance with yaw uncorrected
14	Comparative curves of large total resistance with yaw corrected
15	Comparative curves of large residual resistance with yaw uncorrected
16	Comparative curves of large residual resistance with yaw corrected
17	Comparison of sectional-area curves
18A	Recommended standards for formed rule ends. Lines development
18B	Recommended standards "straight element form" Lines development
19	Increase in resistance resulting from yaw-correcting skogs
20	Standard skog development

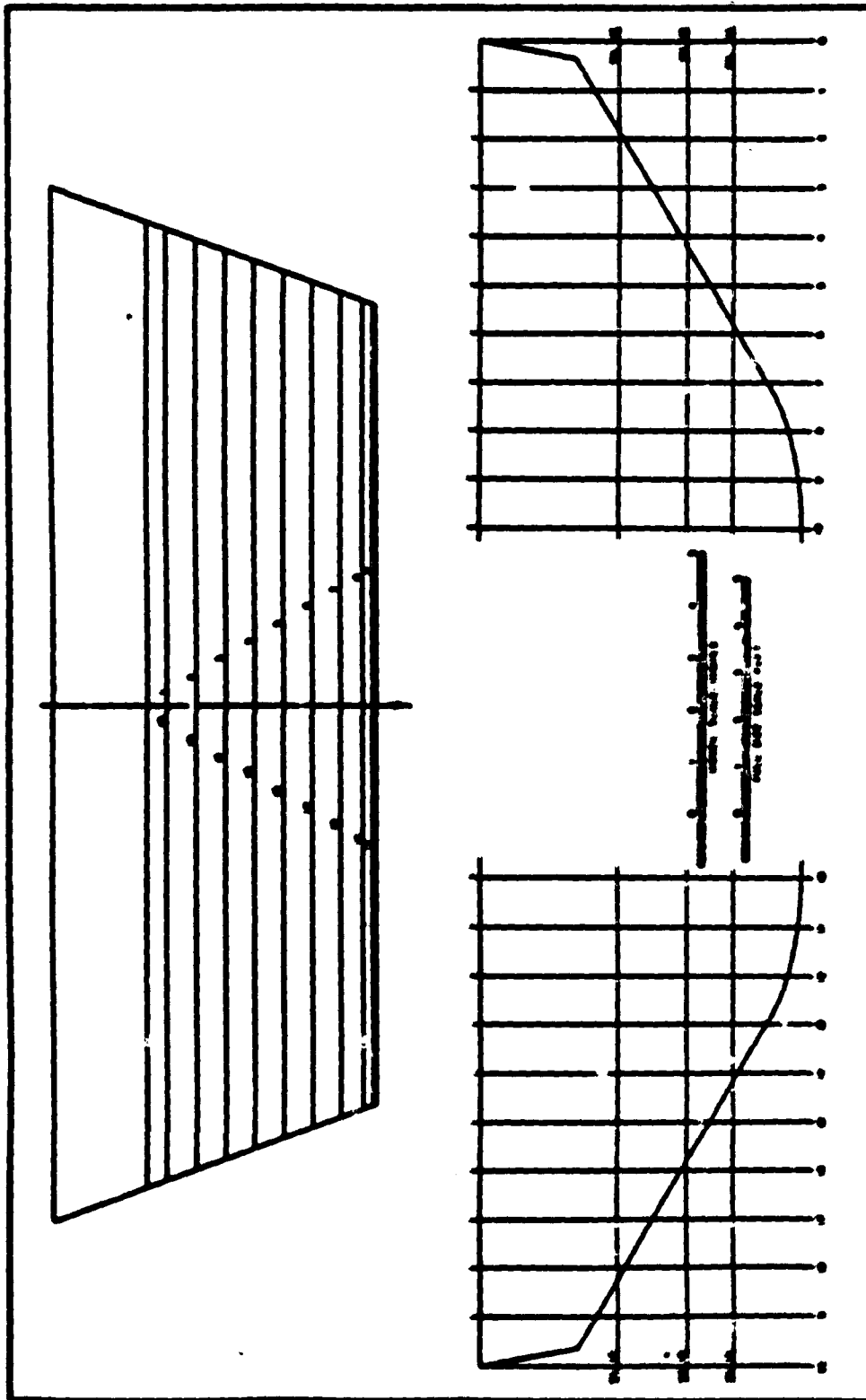


Figure 1A. Design 7001, 81-foot nesting barge. Model lines drawing.

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APPENDIX III (contd)

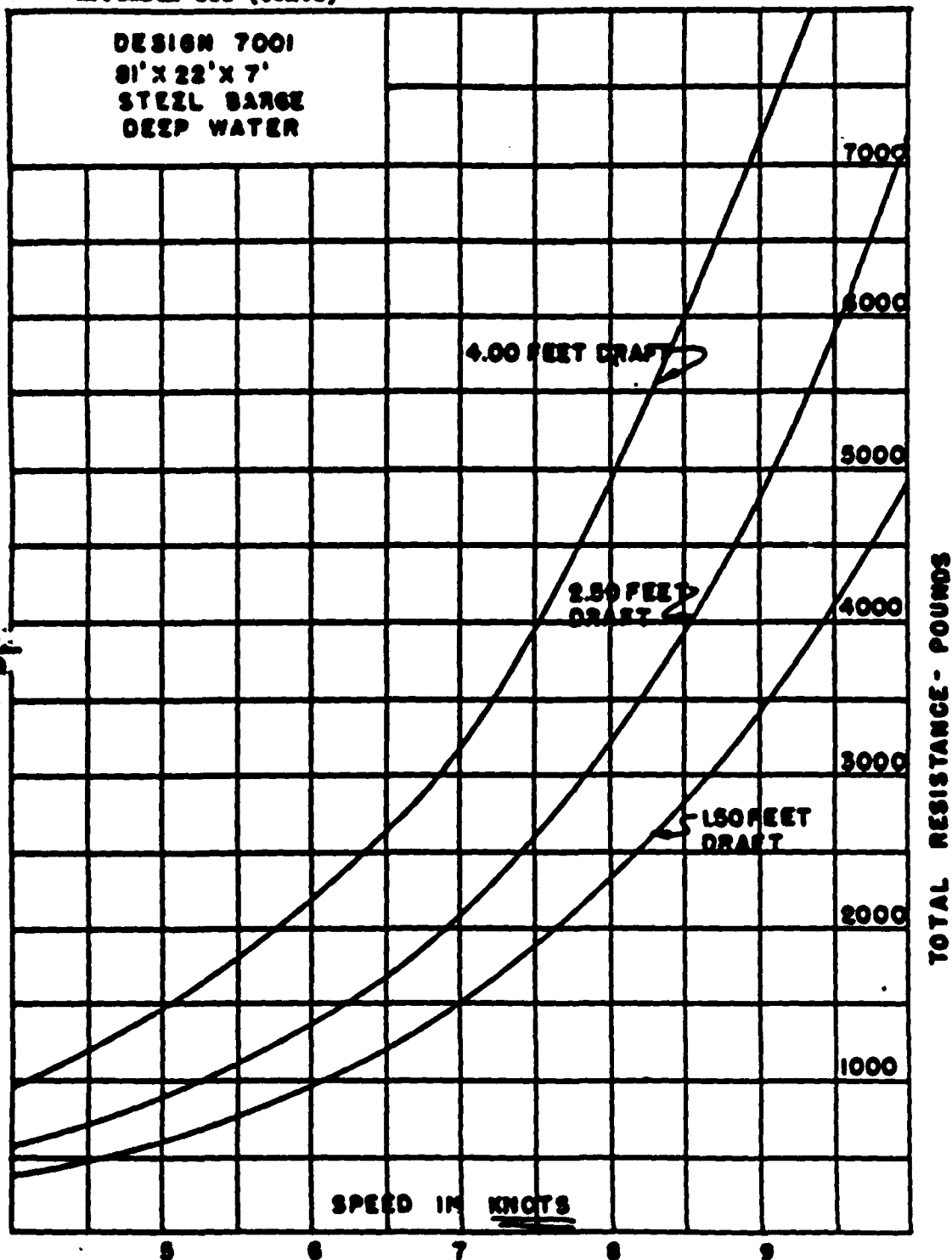


Figure 1B. Design 7001. Curves of total resistance.

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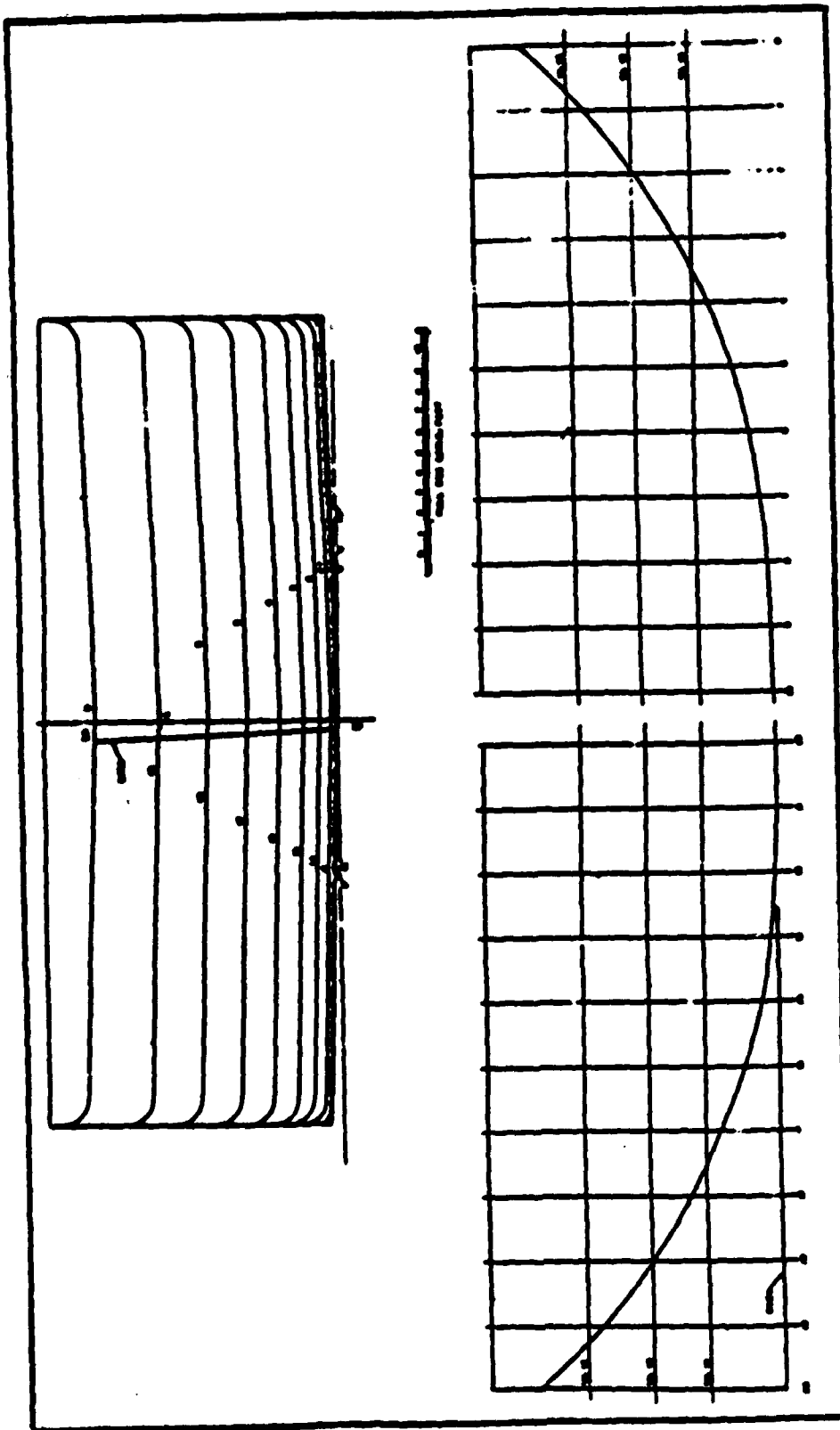


Figure 2A. Design 231 A, 120-foot cargo barge. Model lines drawing.

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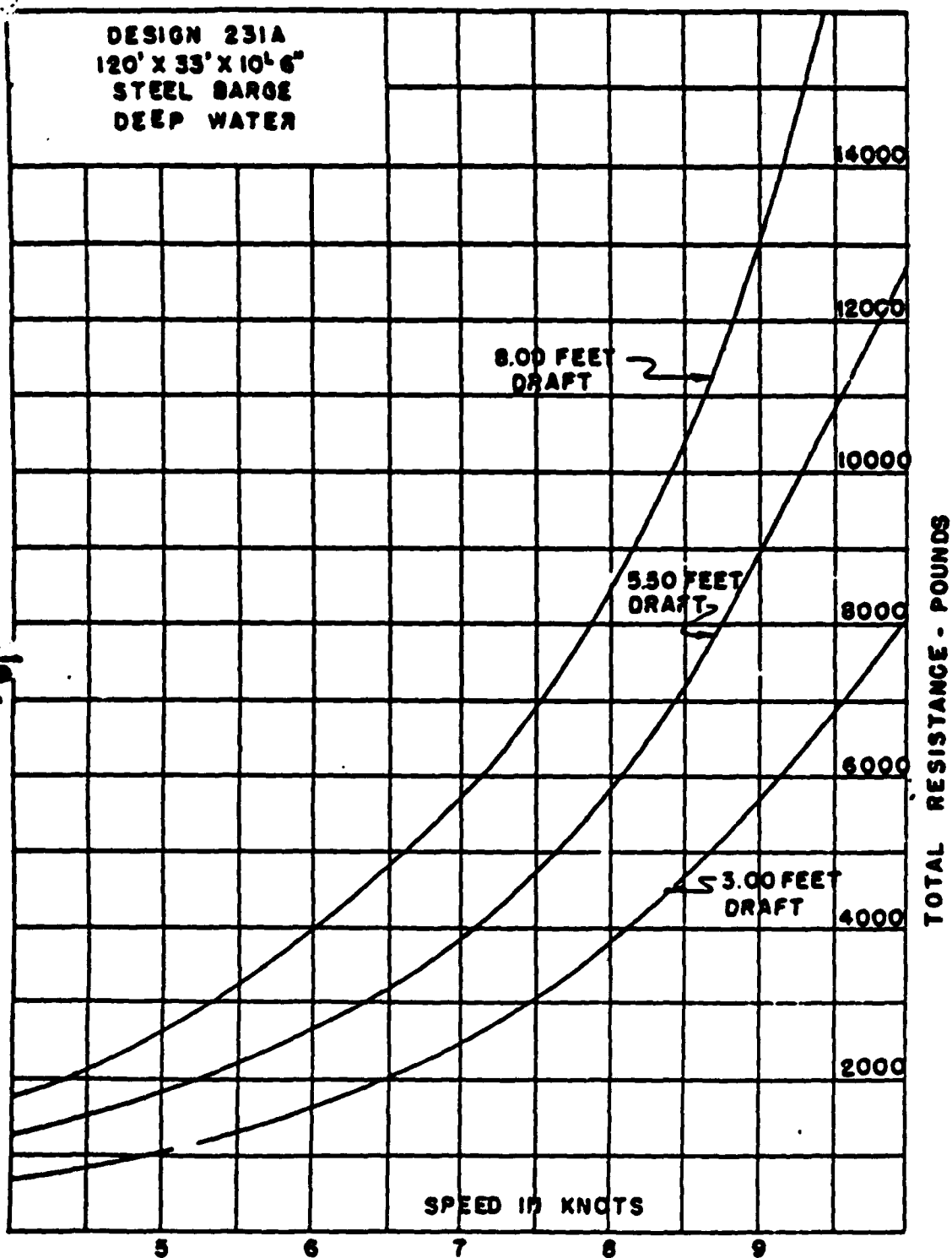


Figure 2B. Design 231 A. Curves of total resistance.

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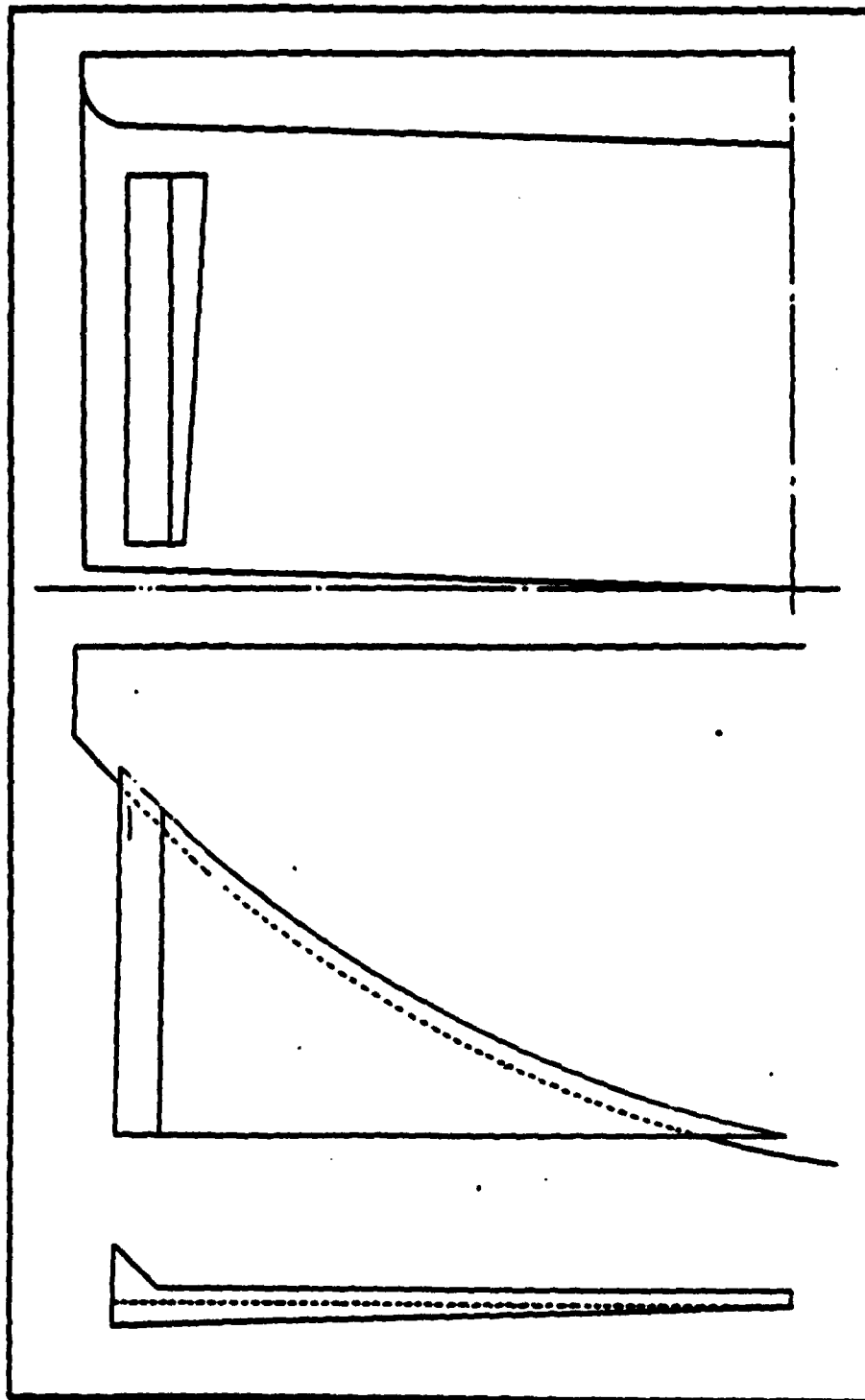


Figure 2C. Design 231 A. Skeg revision.

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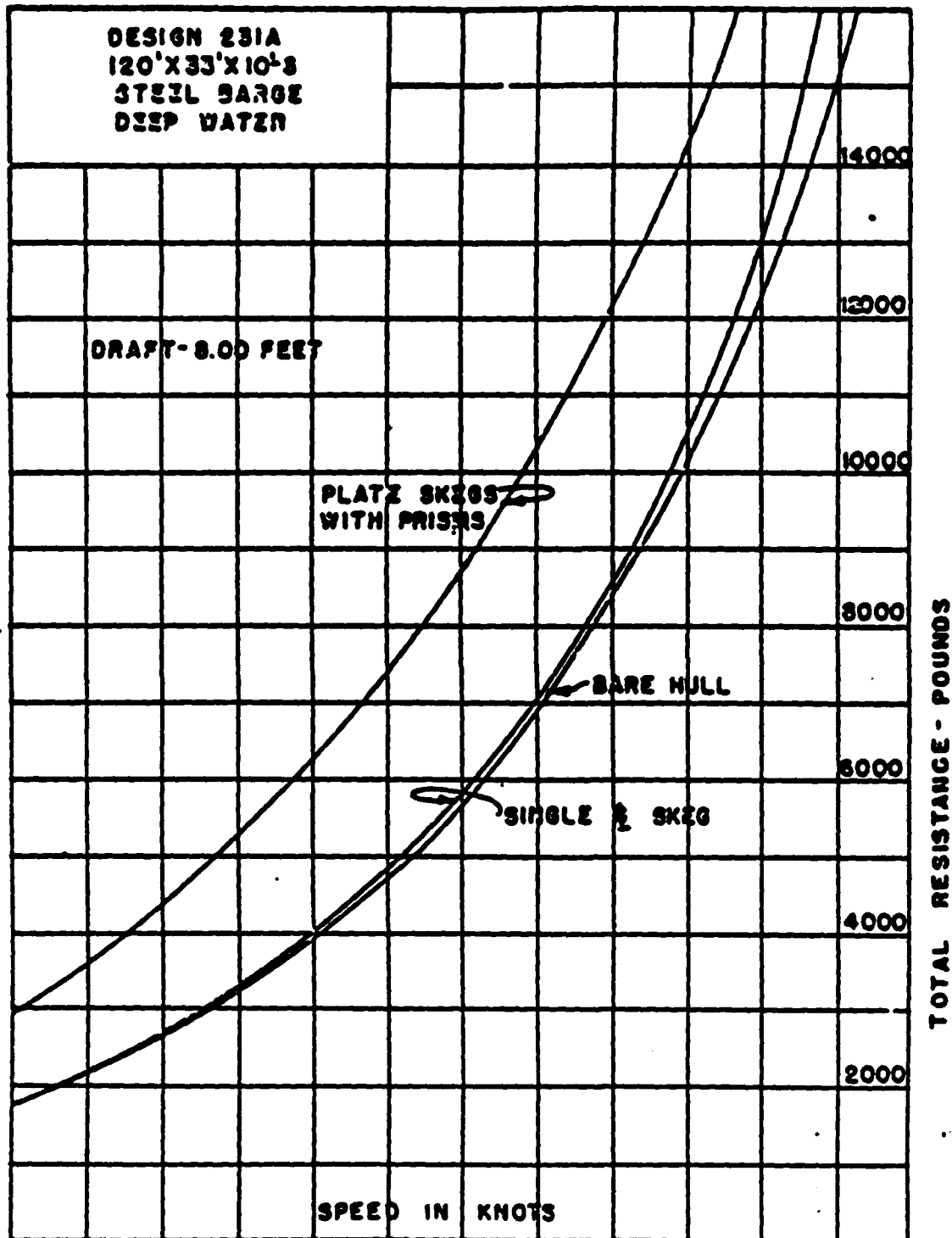
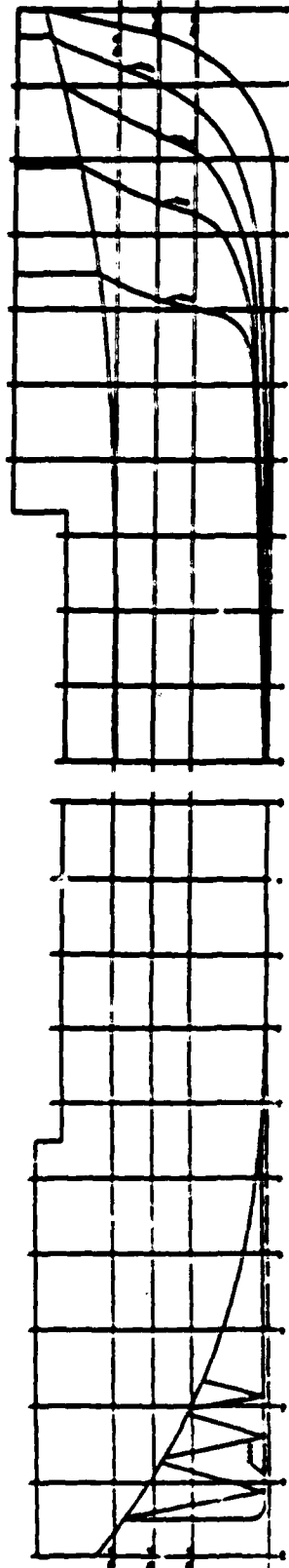
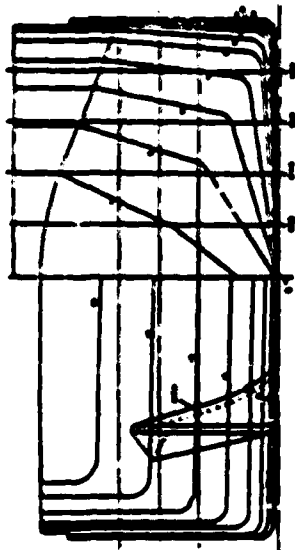


Figure 2D. Design 231 A. Curves of total resistance, showing increased resistance resulting from revised skag design.

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FIGURE 20

APPROX 111 (cont.)



APPROX 111 (cont.)

Figure 20. Design 200, 710-foot dry-cargo barge. Model flow drawing.

APPROX 111

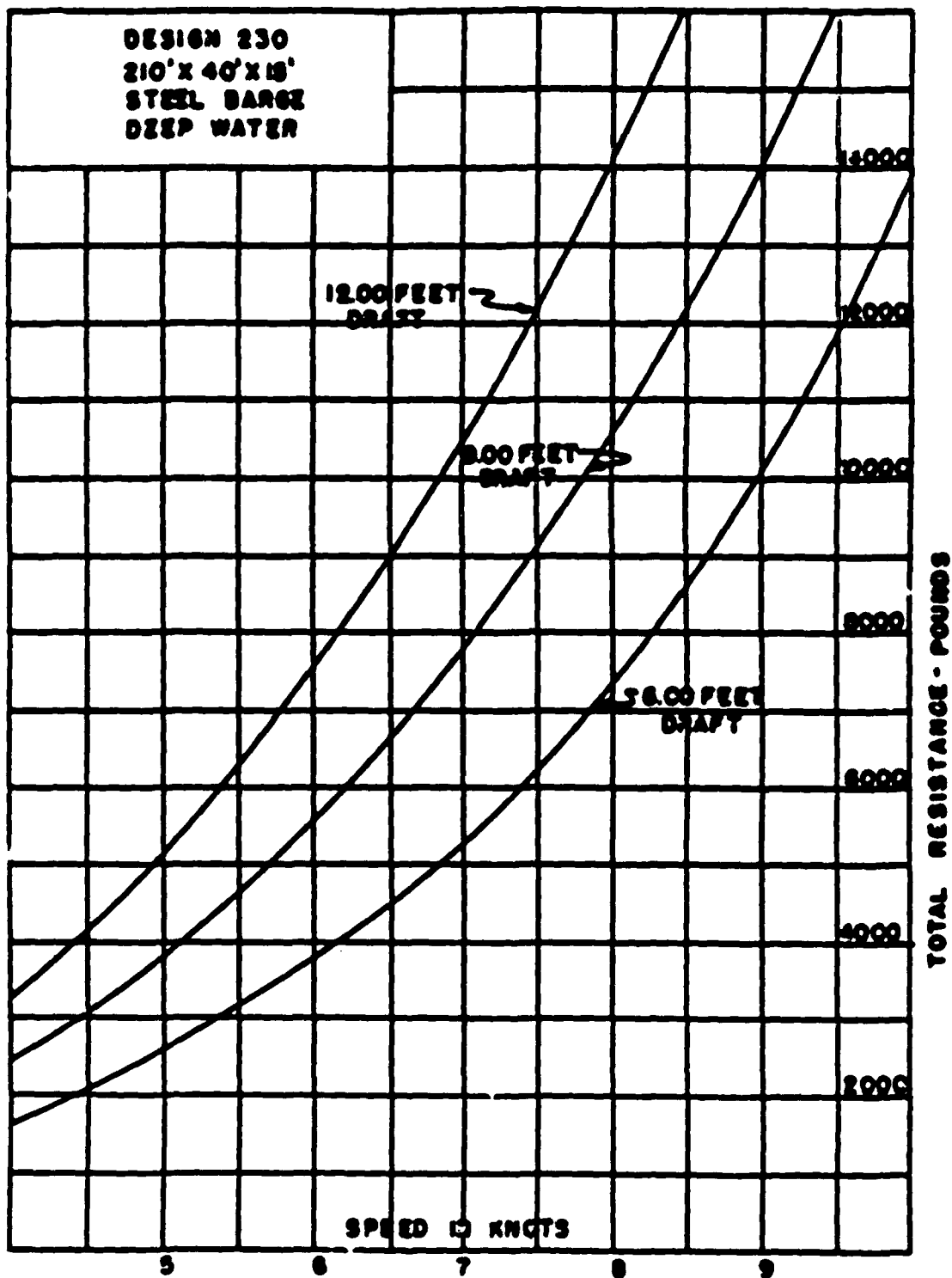


Figure 3B. Design 230. Curves of total resistance.

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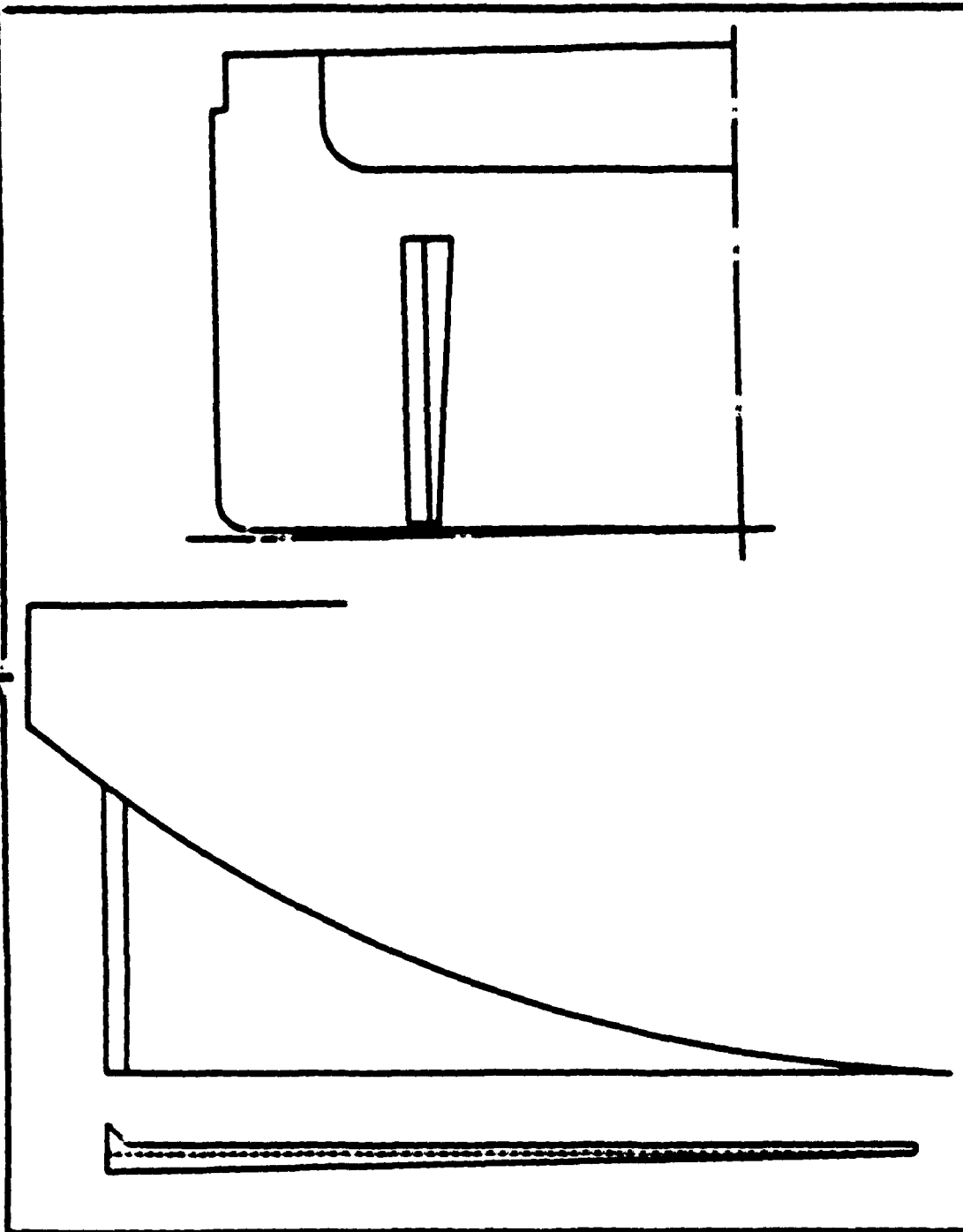


Figure 3C. Design 230. Ship revision.

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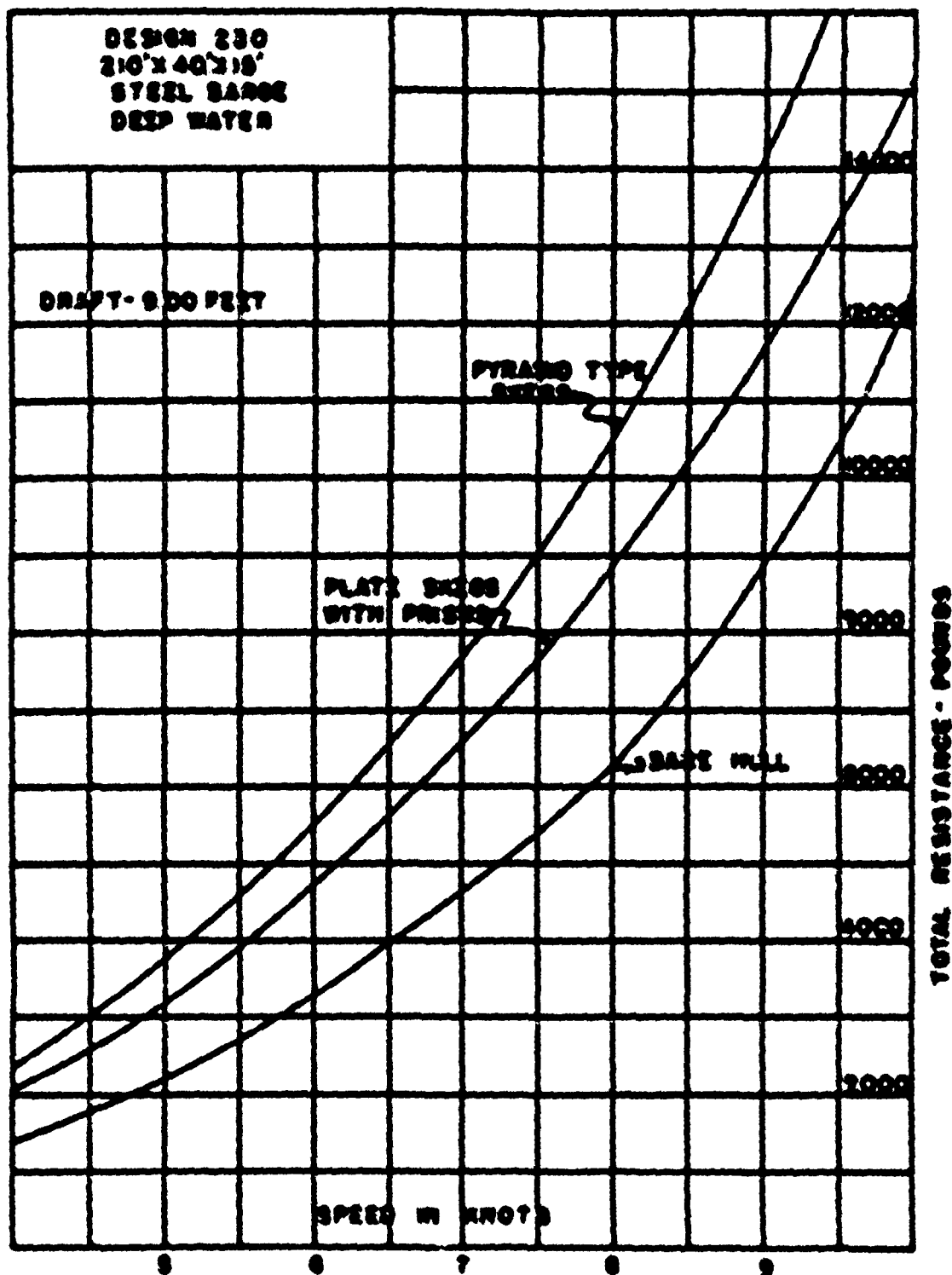


Figure 2B. Design 230. Curves of total resistance, showing change in resistance resulting from revised skeg design.

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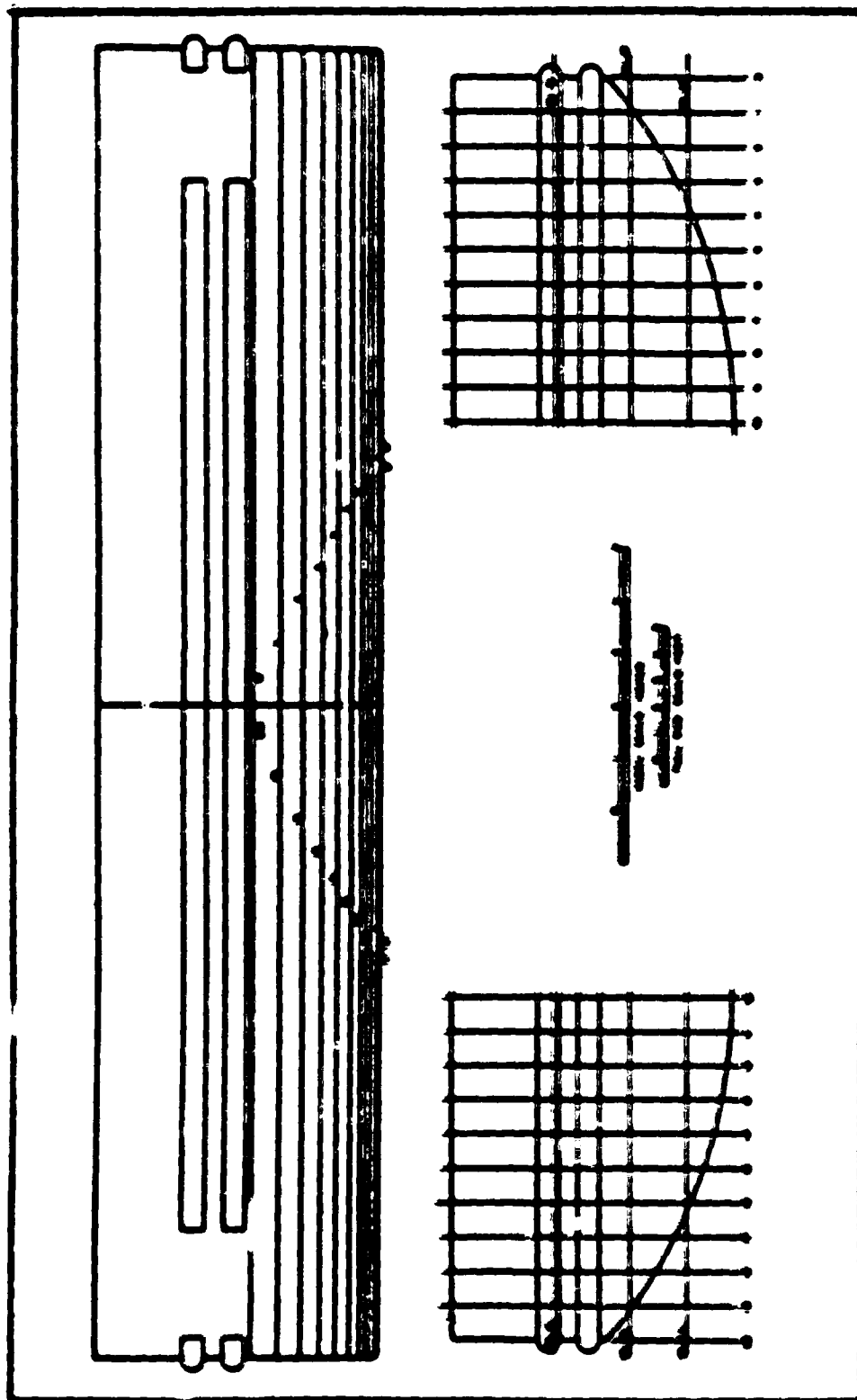


Figure 4A. Design 305, 150-foot pier large. Model lines drawing.

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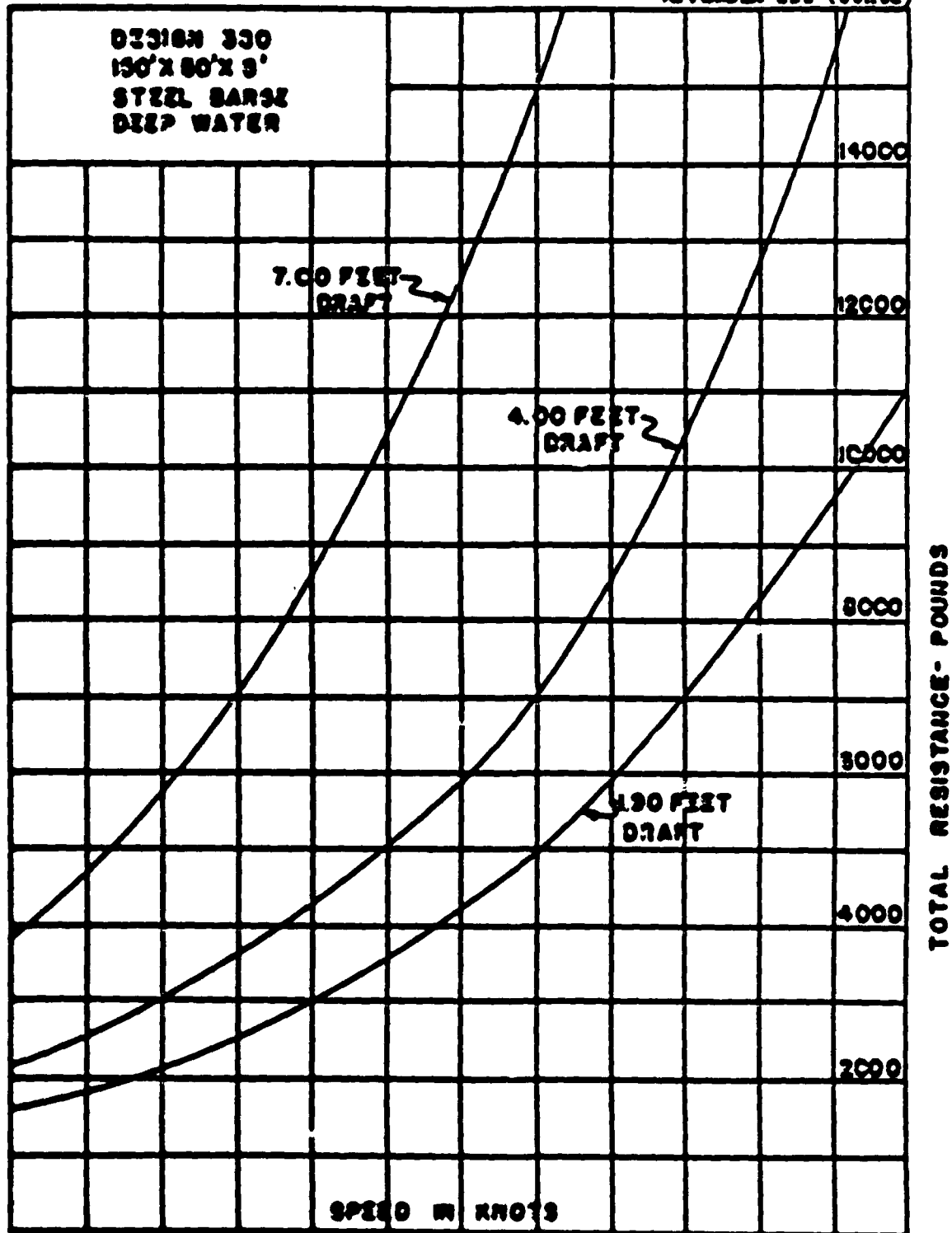


Figure 42. Design 330. Curves of total resistance.

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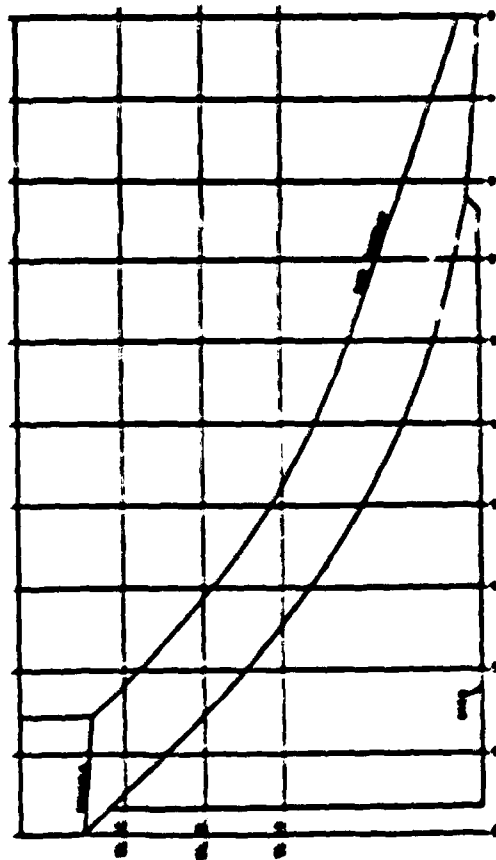
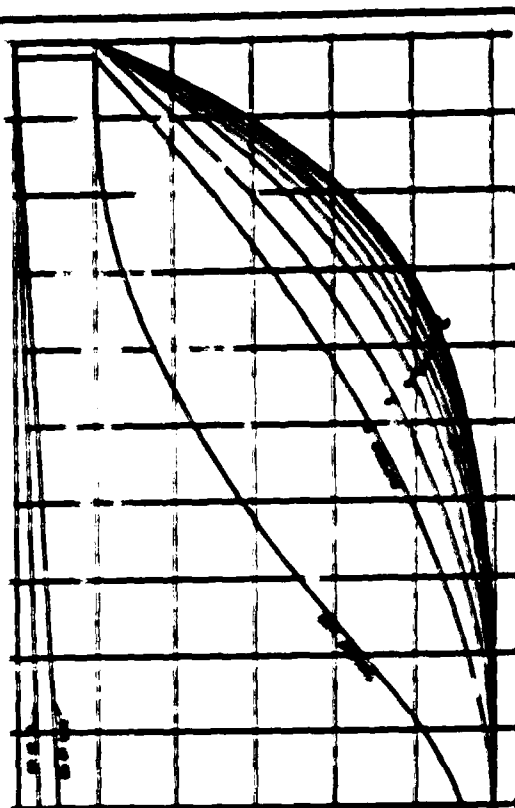
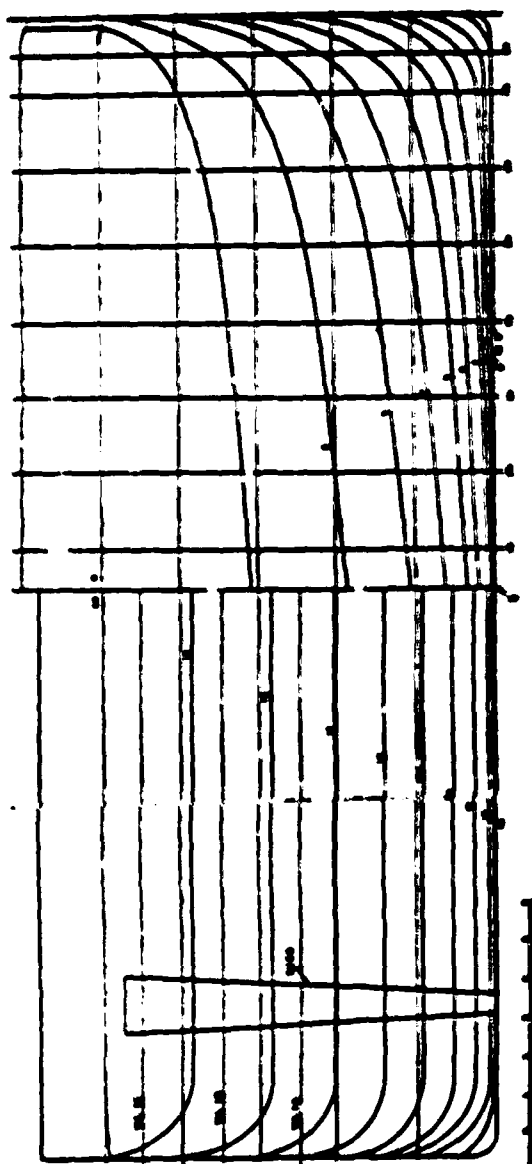


Figure 24. Section 247, 135-foot core logs. Initial time drawing of numbers

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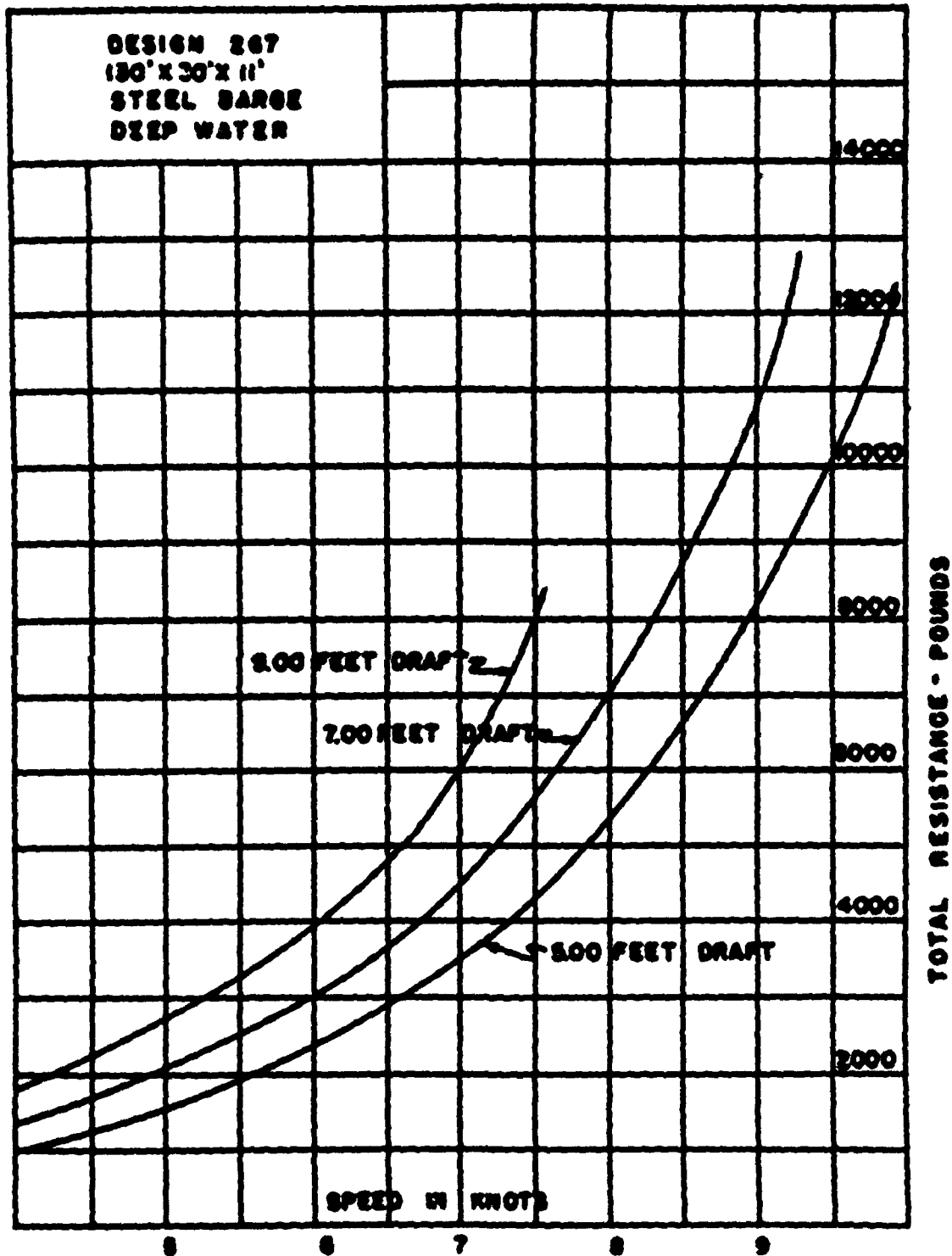


Figure 5B. Design 267. Curves of total resistance.

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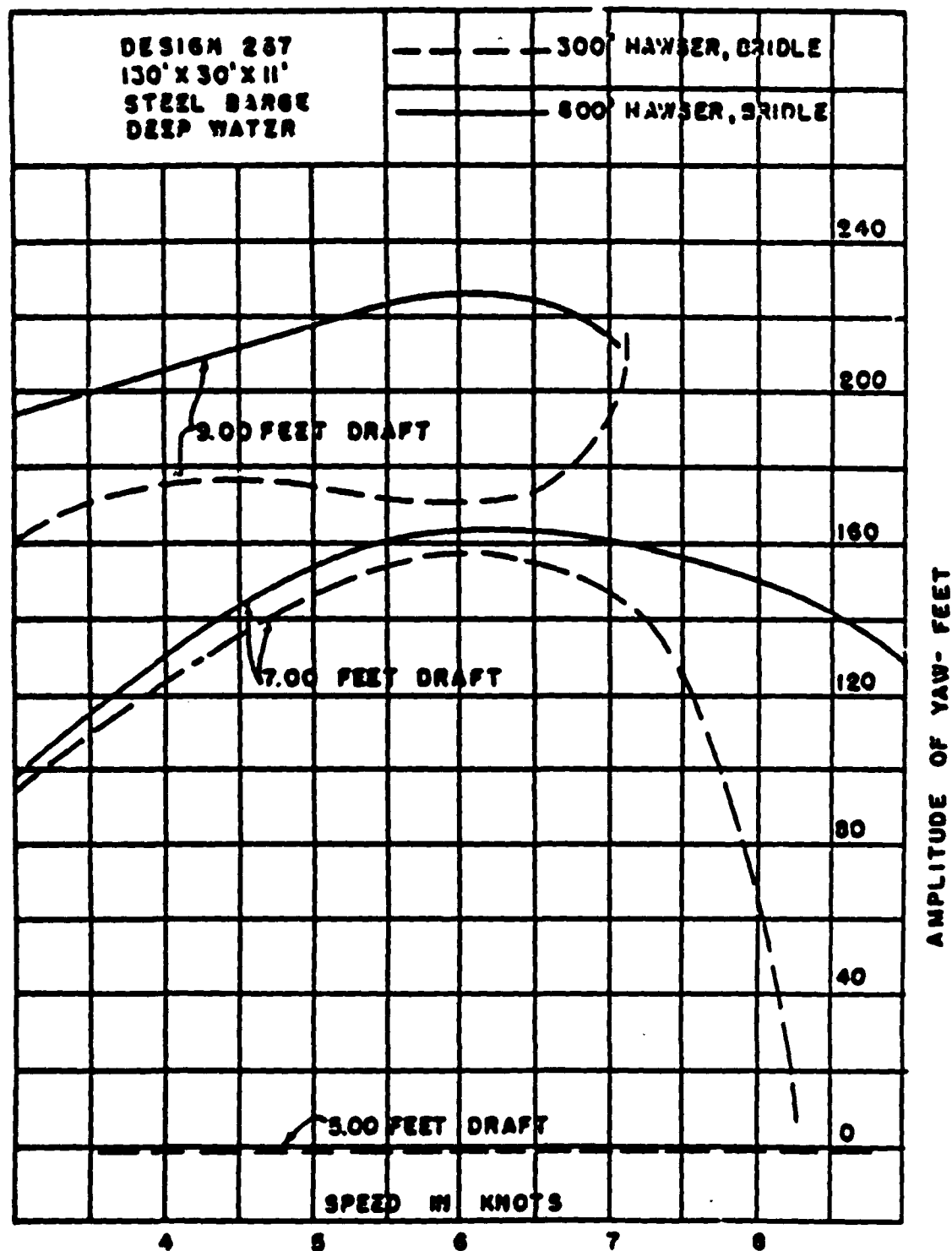


Figure SC. Design 267. Curves of yaw amplitude.

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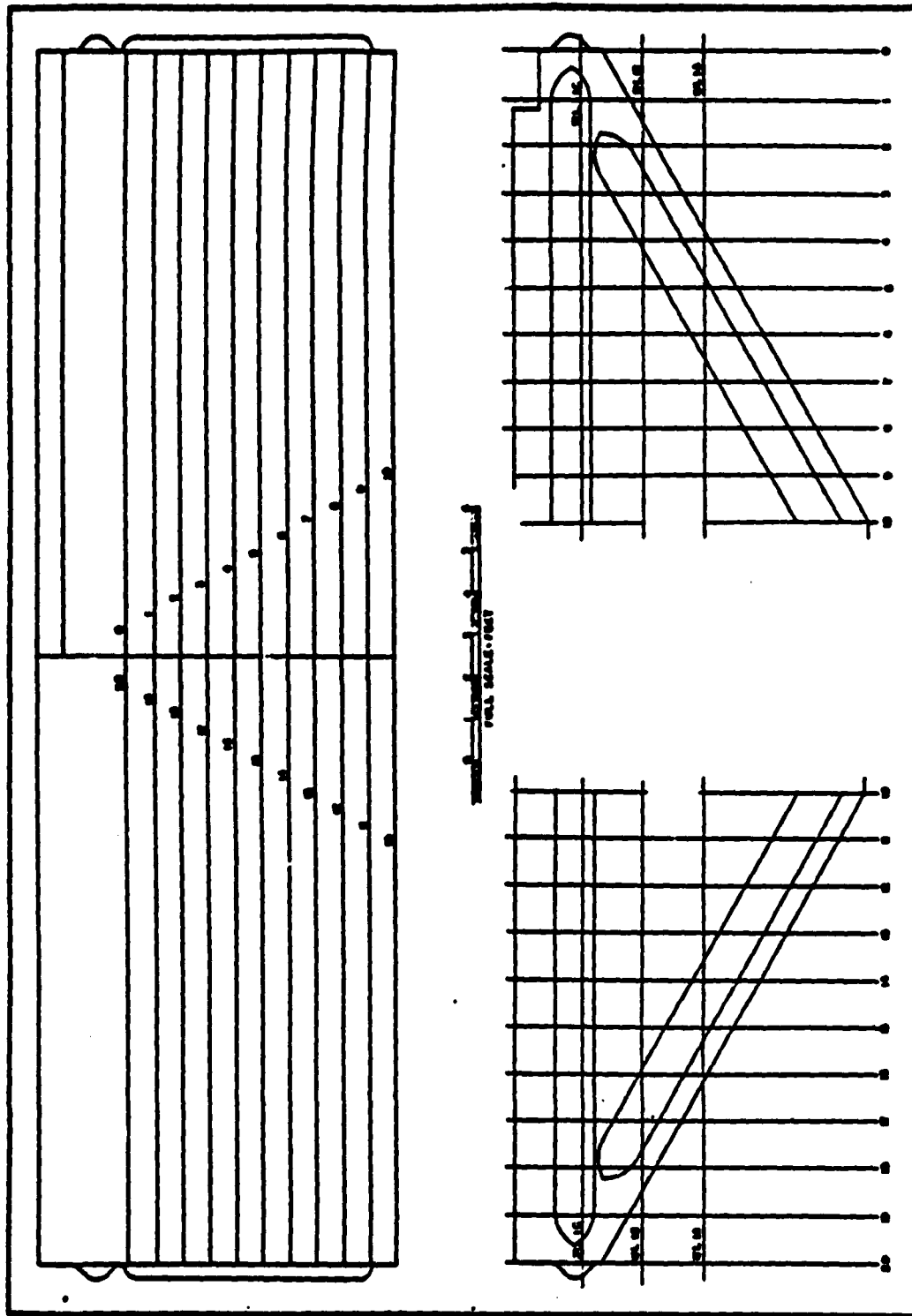


Figure 6A. Design 430, 112-foot knock-down fuel-oil cargo barge. Model lines drawings.

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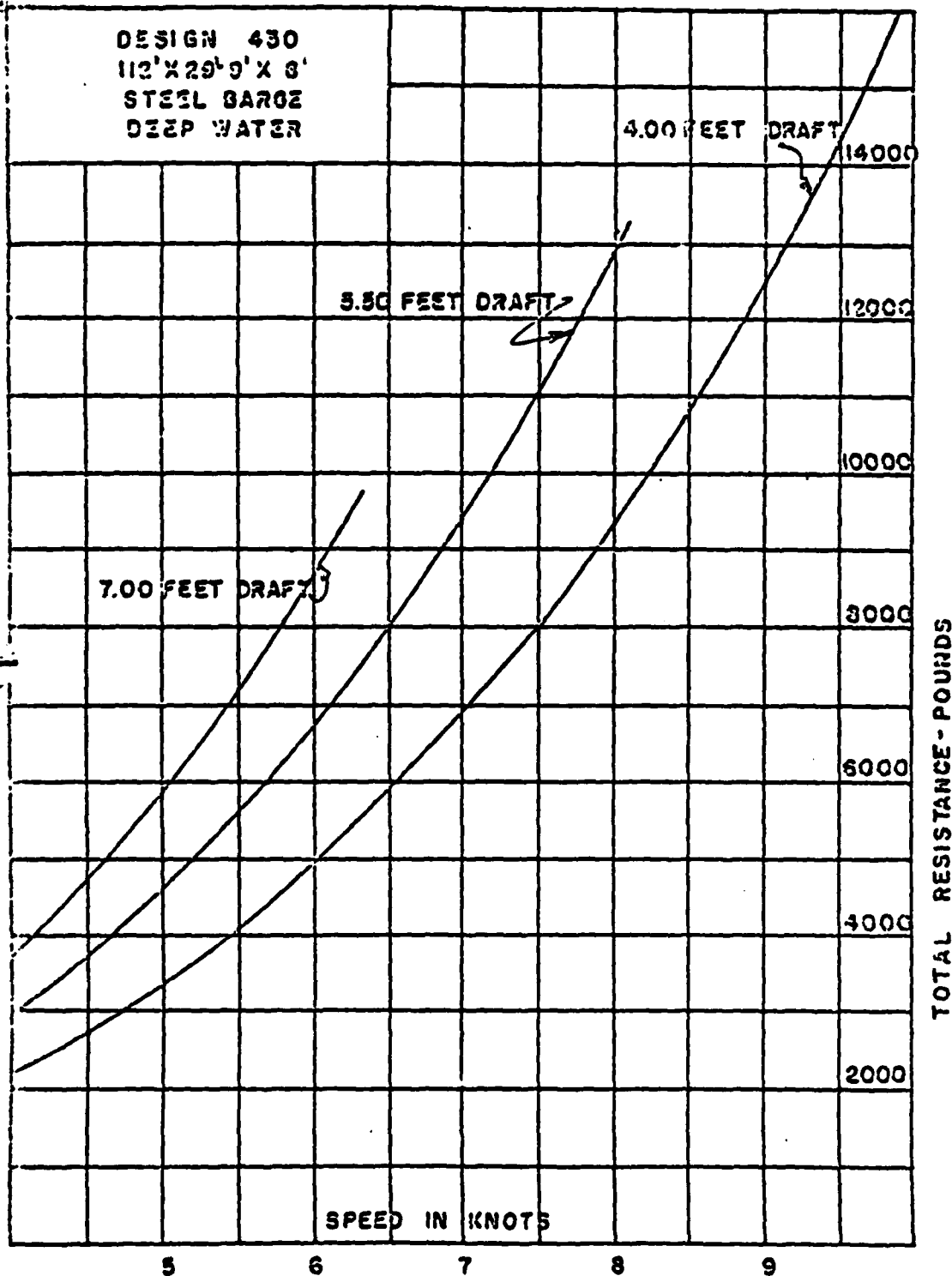


Figure 6B. Design 430. Curves of total resistance.

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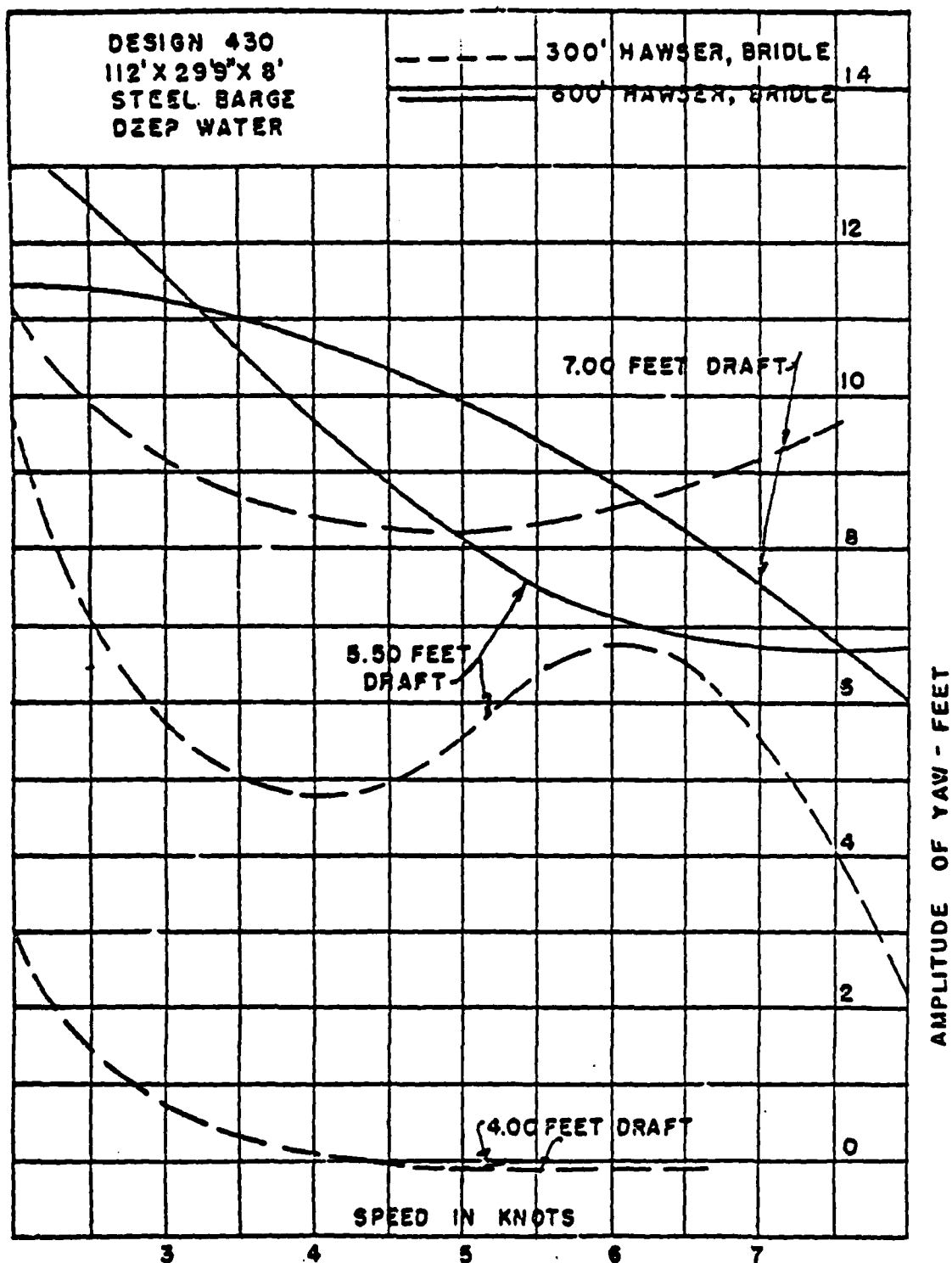


Figure 6C. Design 430. Curves of yaw amplitude.

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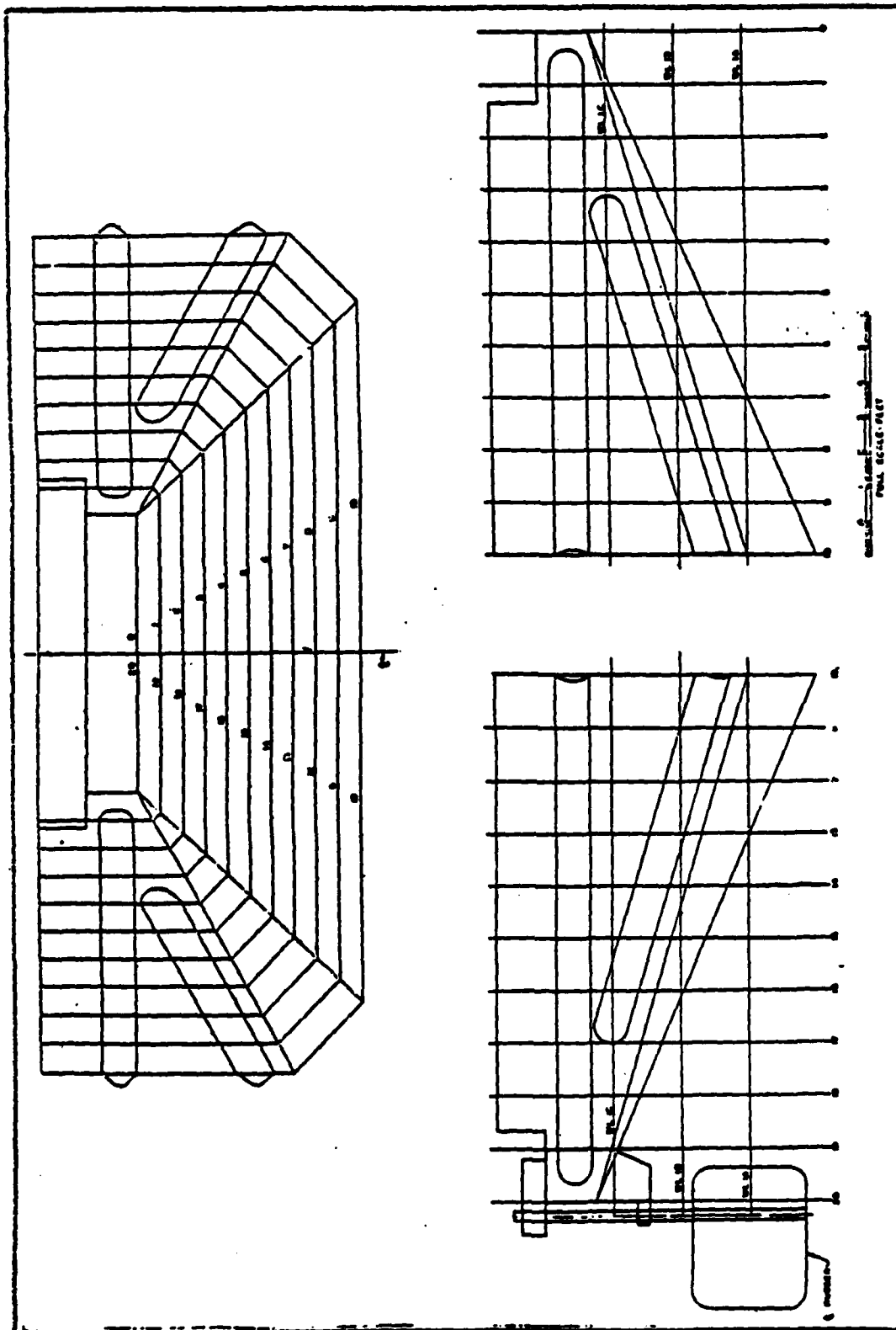


Figure 7A. Design 417 S, 112-foot steel dry-cargo barge. Model lines drawing.

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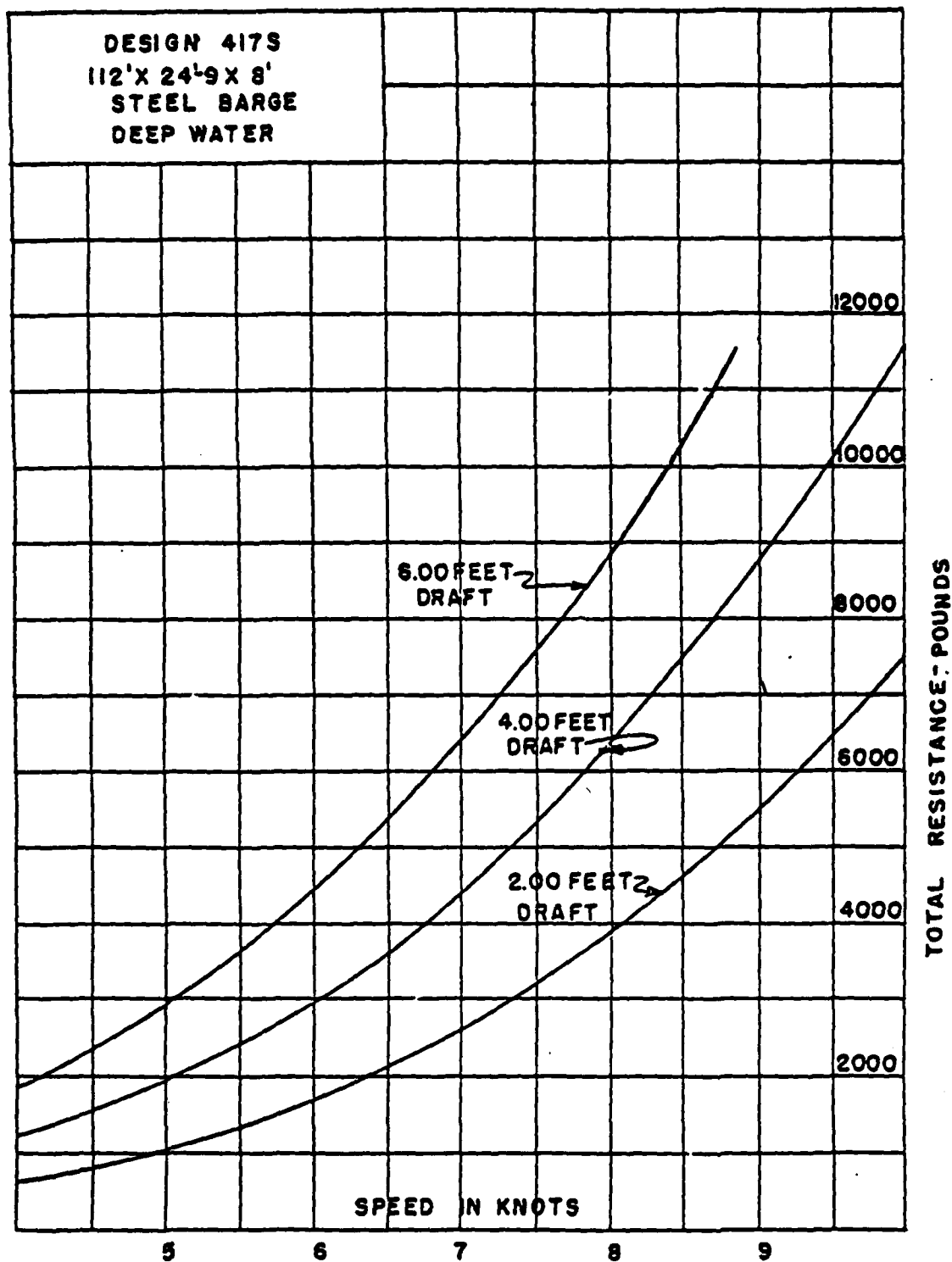


Figure 7B. Design 417 S. Curves of total resistance.

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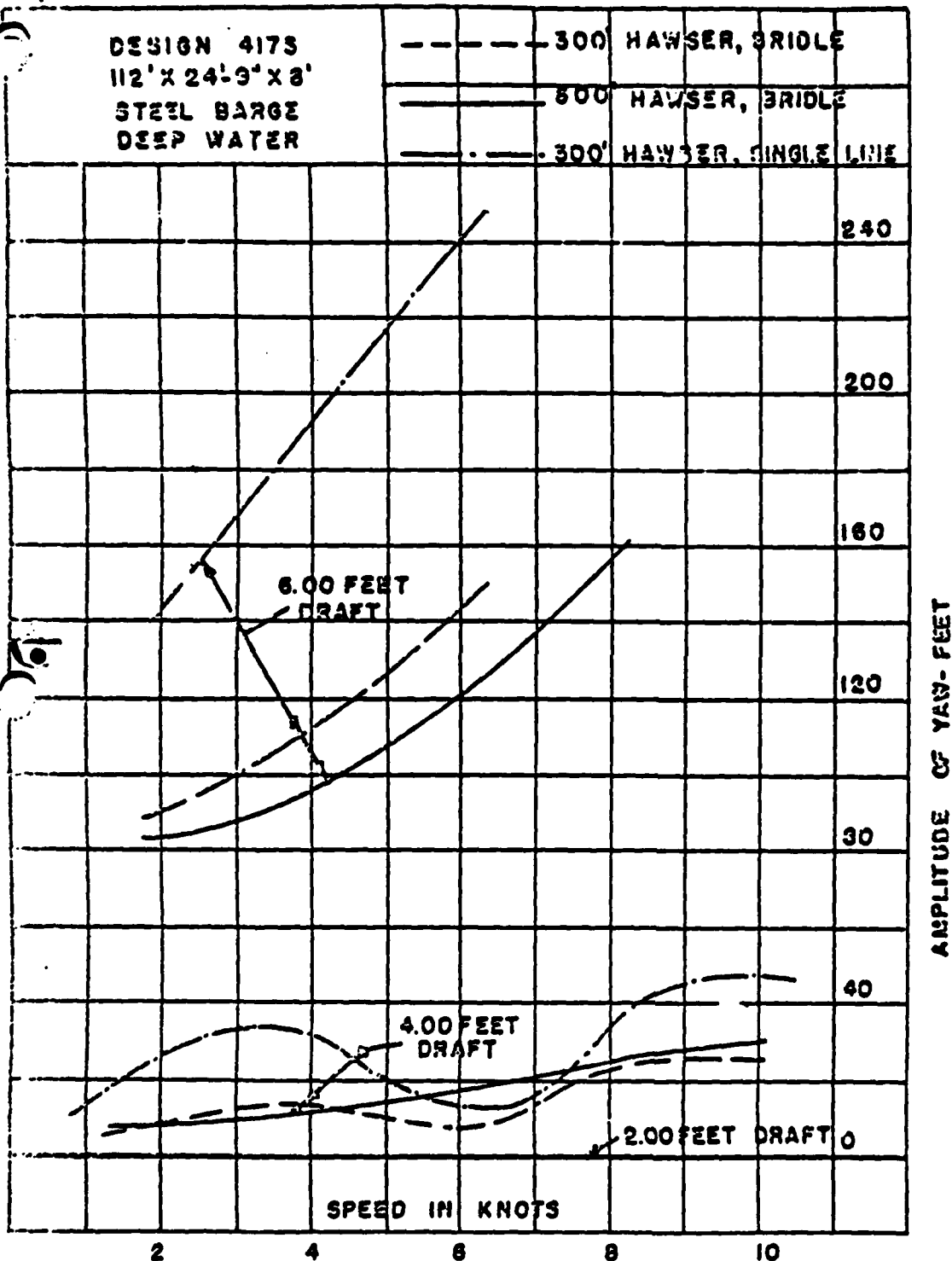


Figure 7C. Design 417 S. Curves of yaw amplitude.

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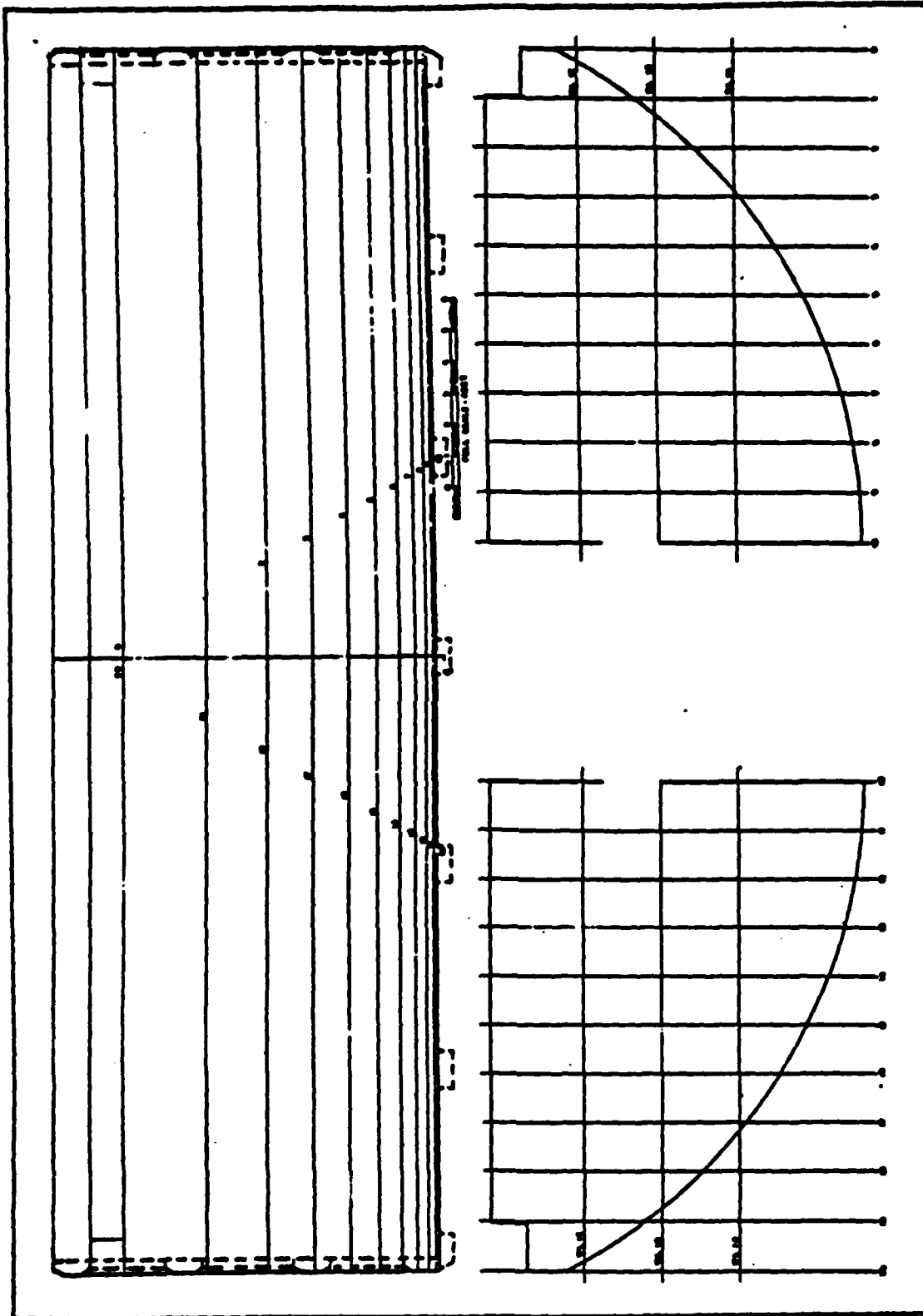


Figure 8A. Design 336 B, 130-foot wooden lighter barge. Model lines drawing.

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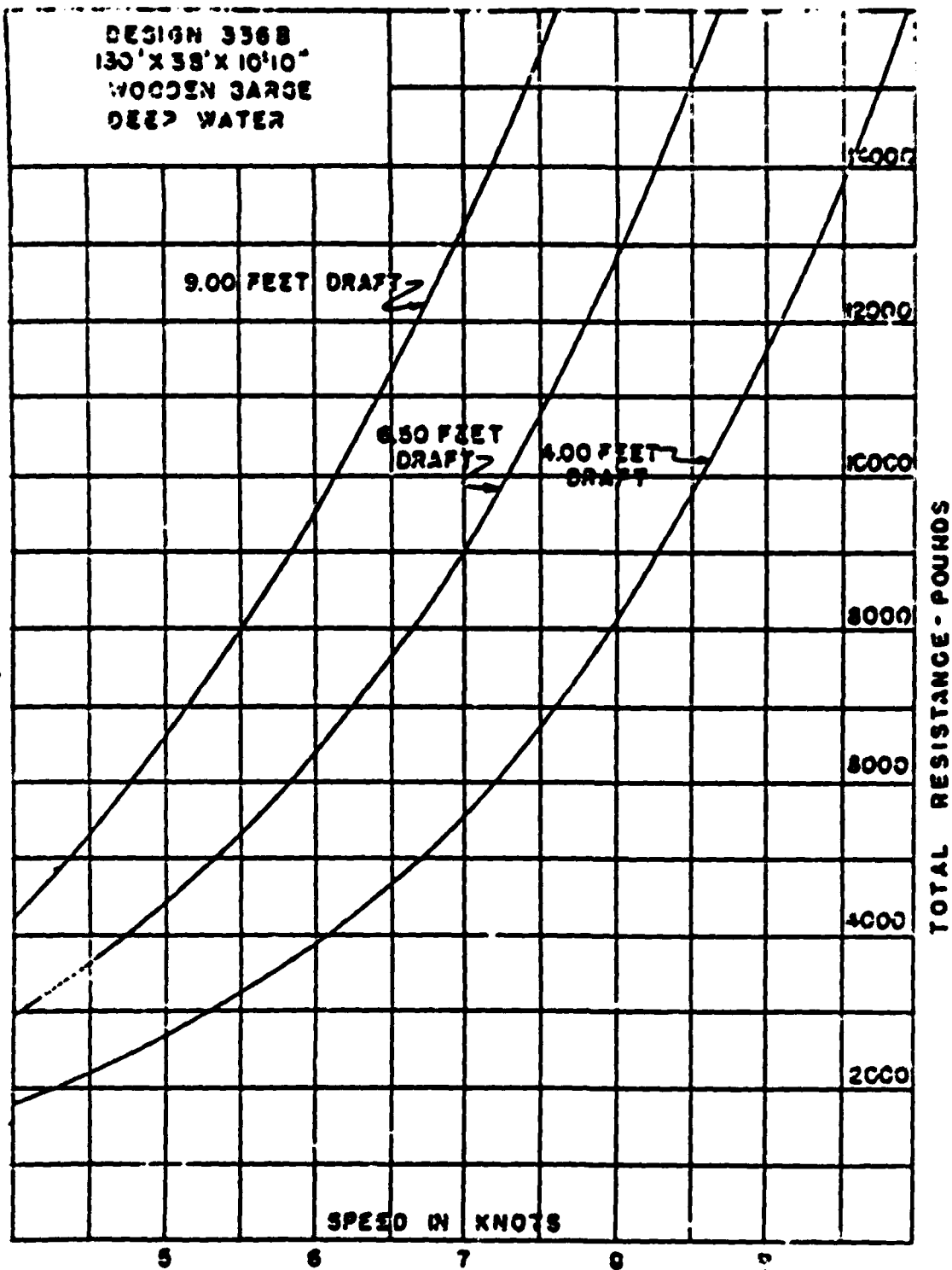


Figure 83. Design 336 B. Curves of total resistance.

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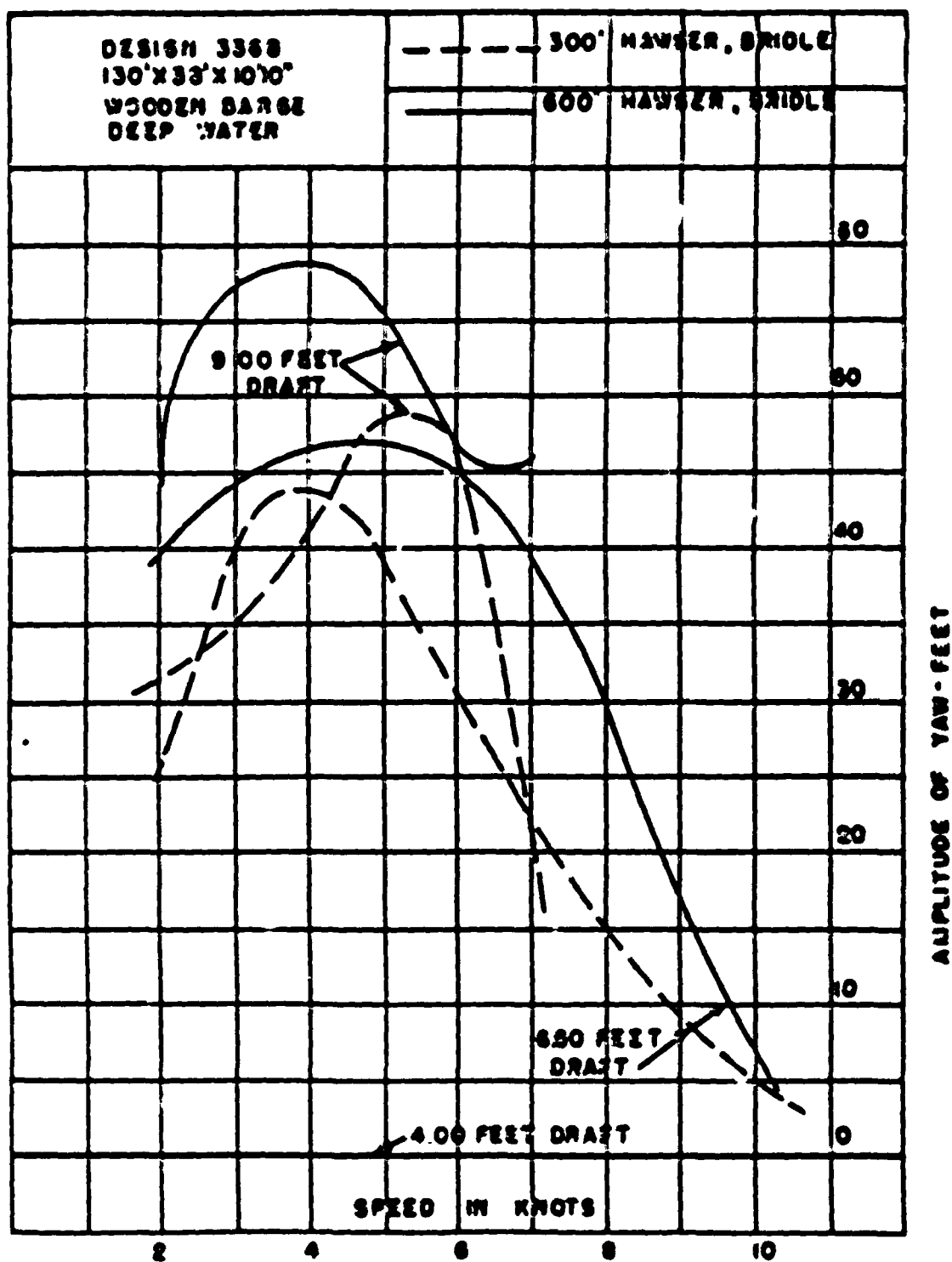


Figure 8C. Design 336 B. Curves of yaw amplitude.

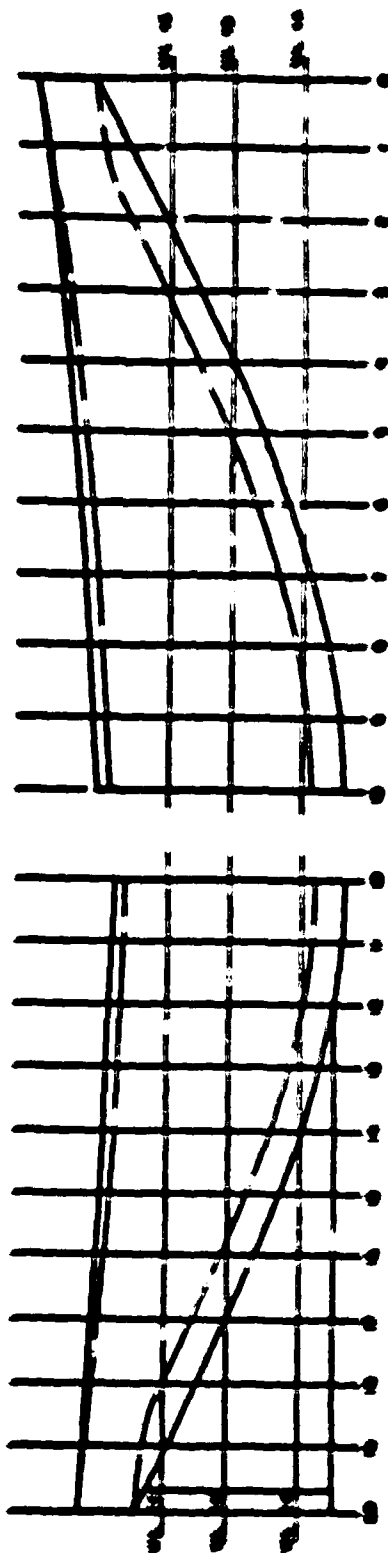
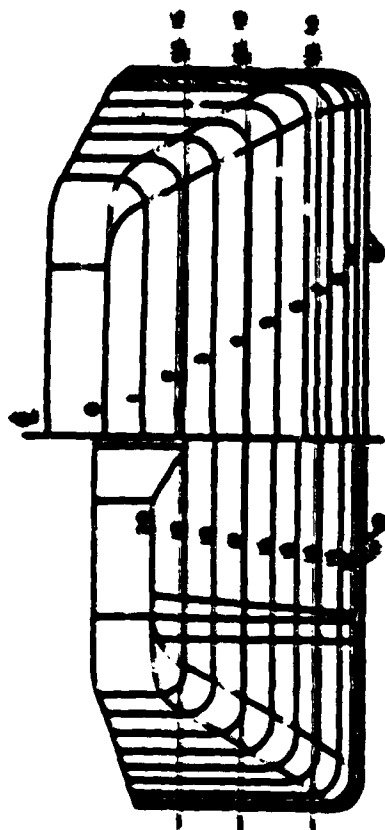


Figure 94. Design 7002, 100-foot steel barge. Model lines drawing.

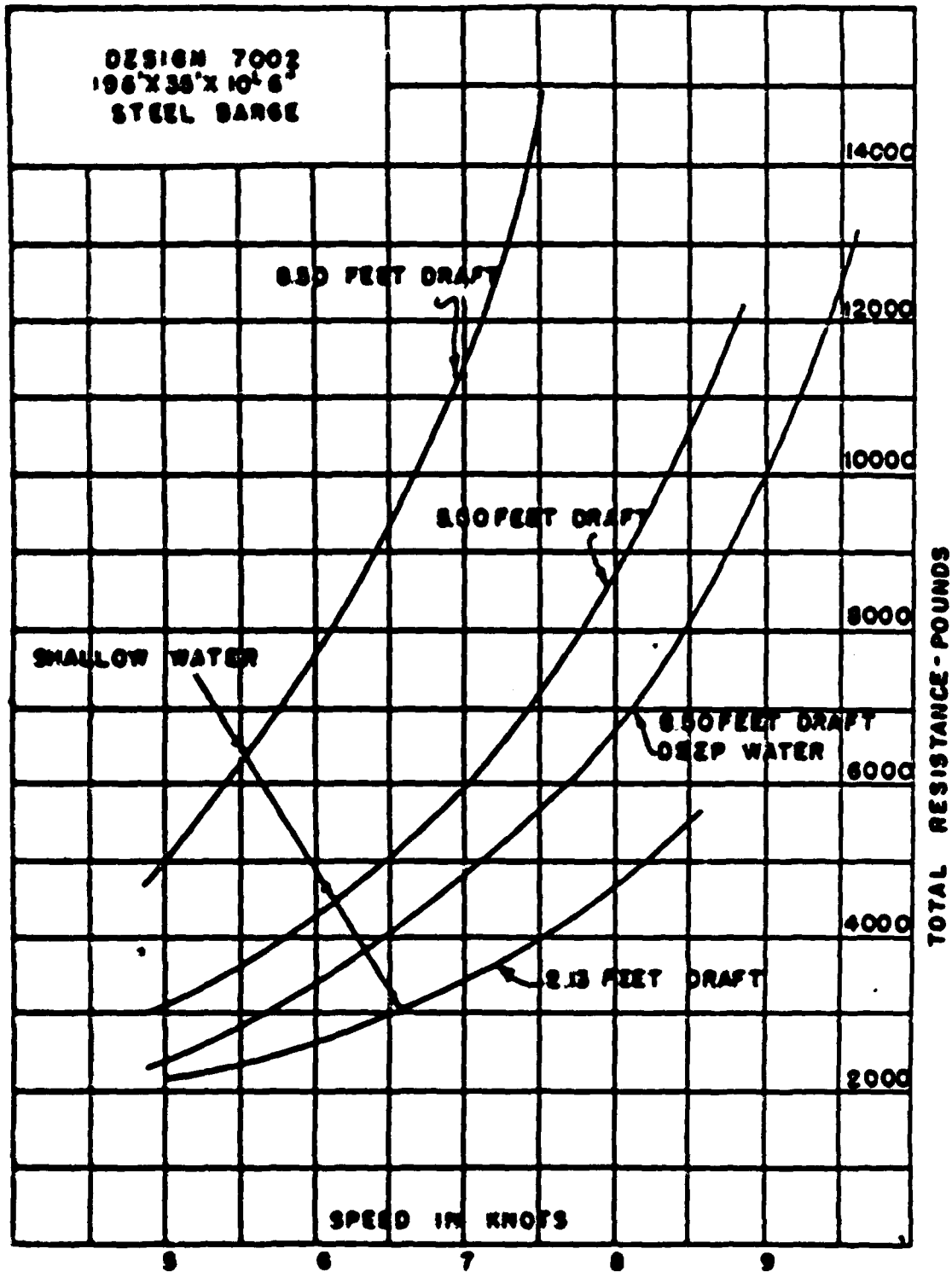


Figure 92. Design 7002. Curves of total resistance.

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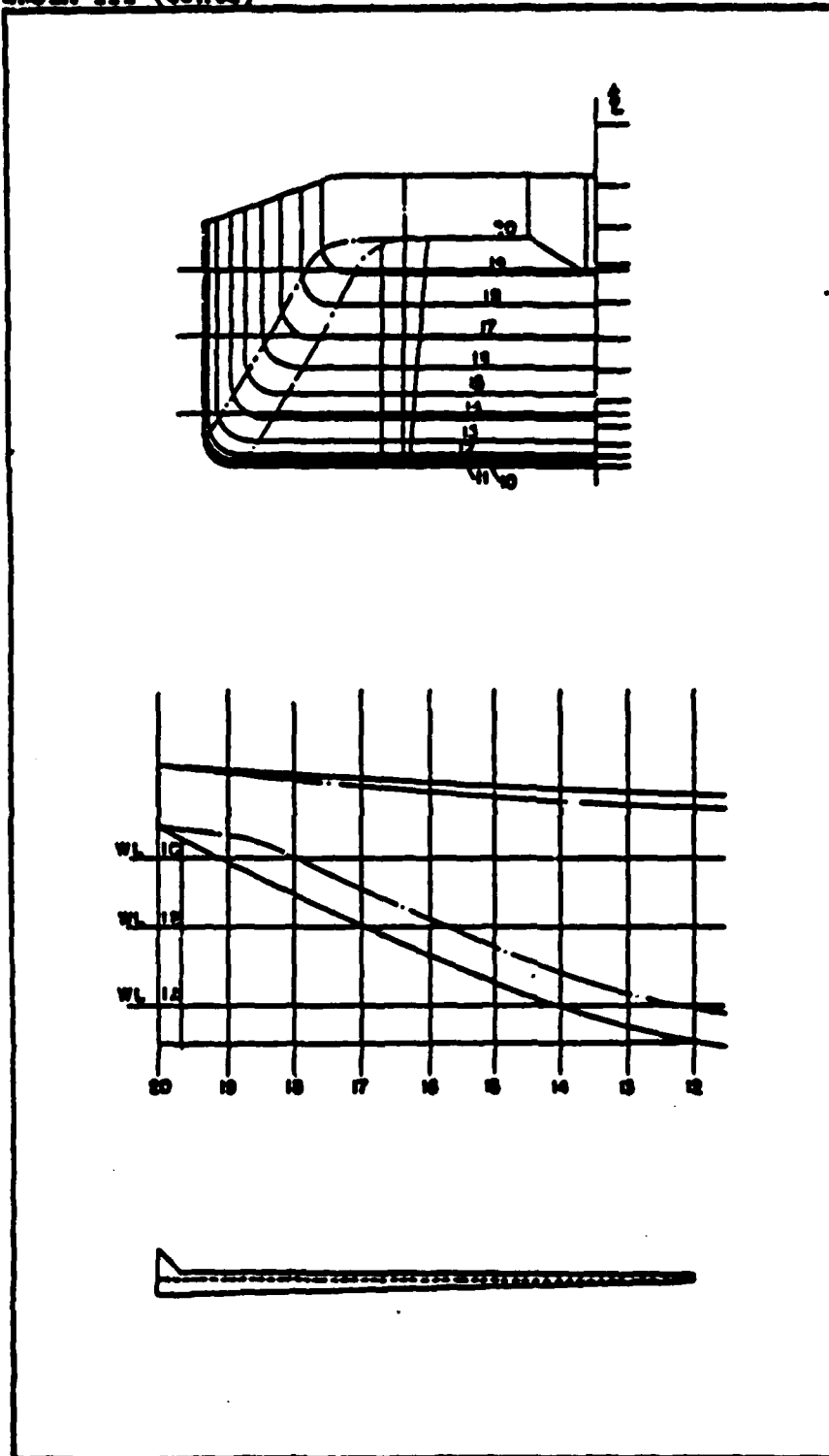


Figure 9C. Design 7002. Skag revision.

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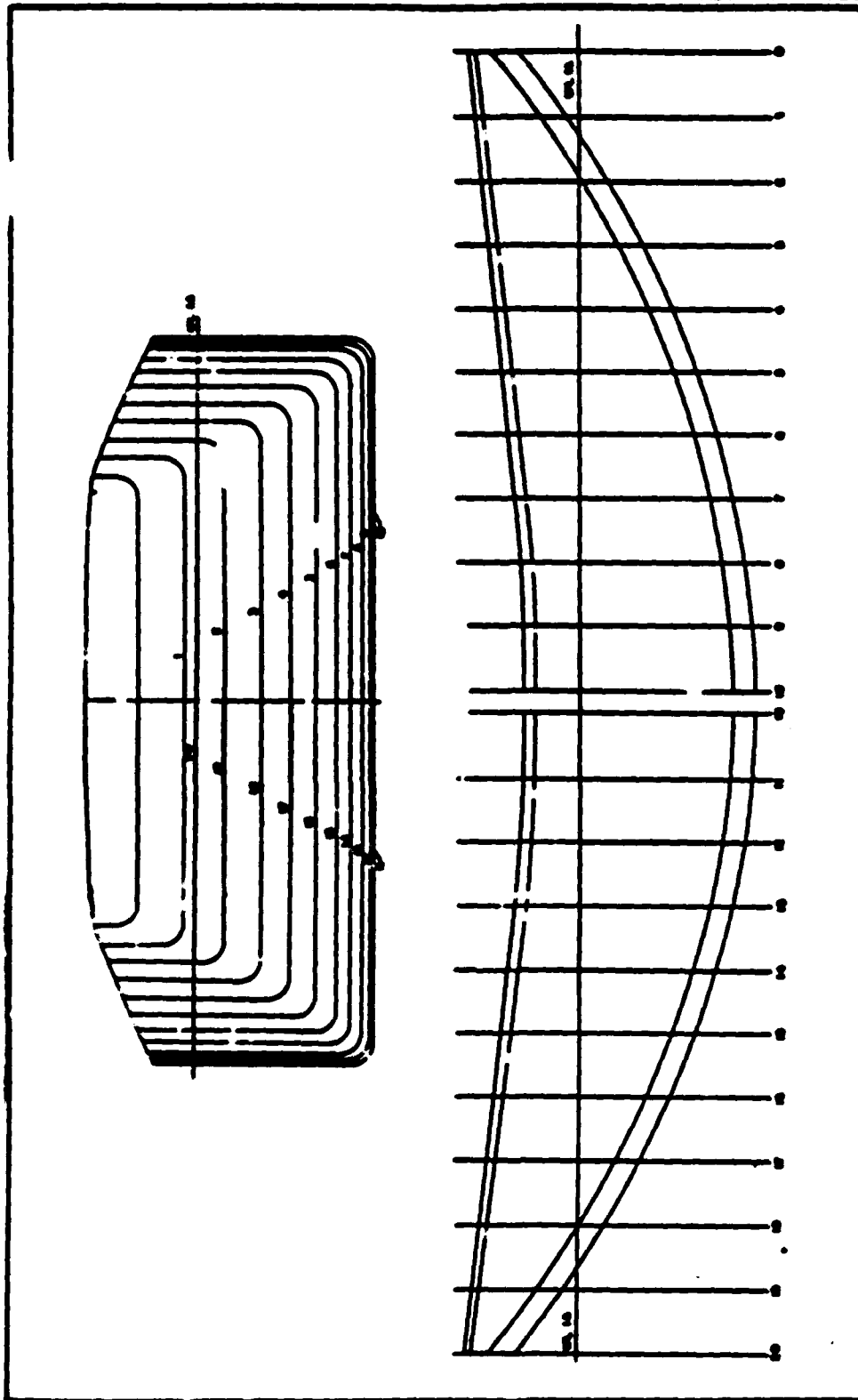


Figure 10A. Design 7003, 130-foot steel barge. Model lines drawing.

APPENDIX III (contd)

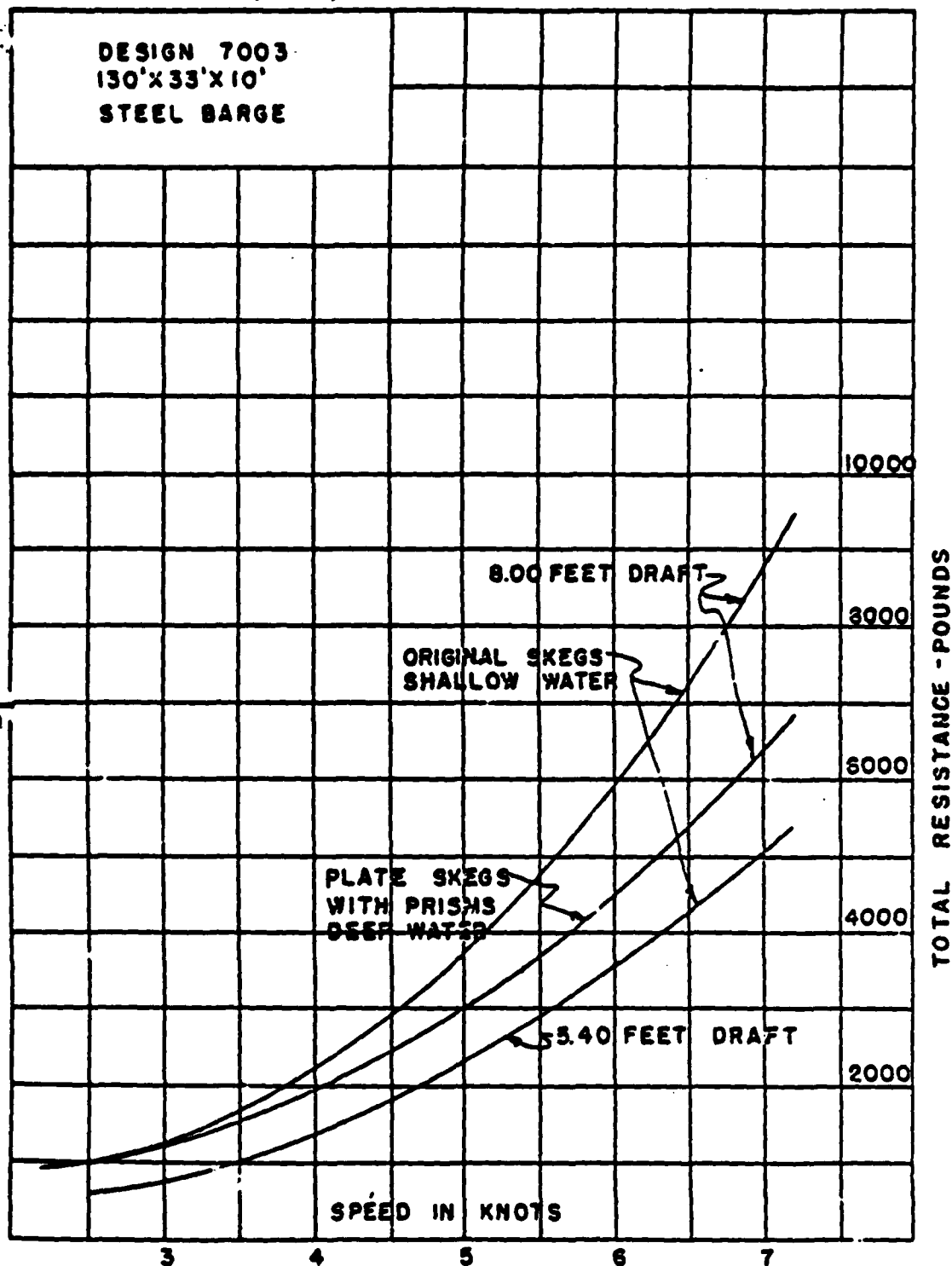


Figure 10B. Design 7003, Curves of total resistance.

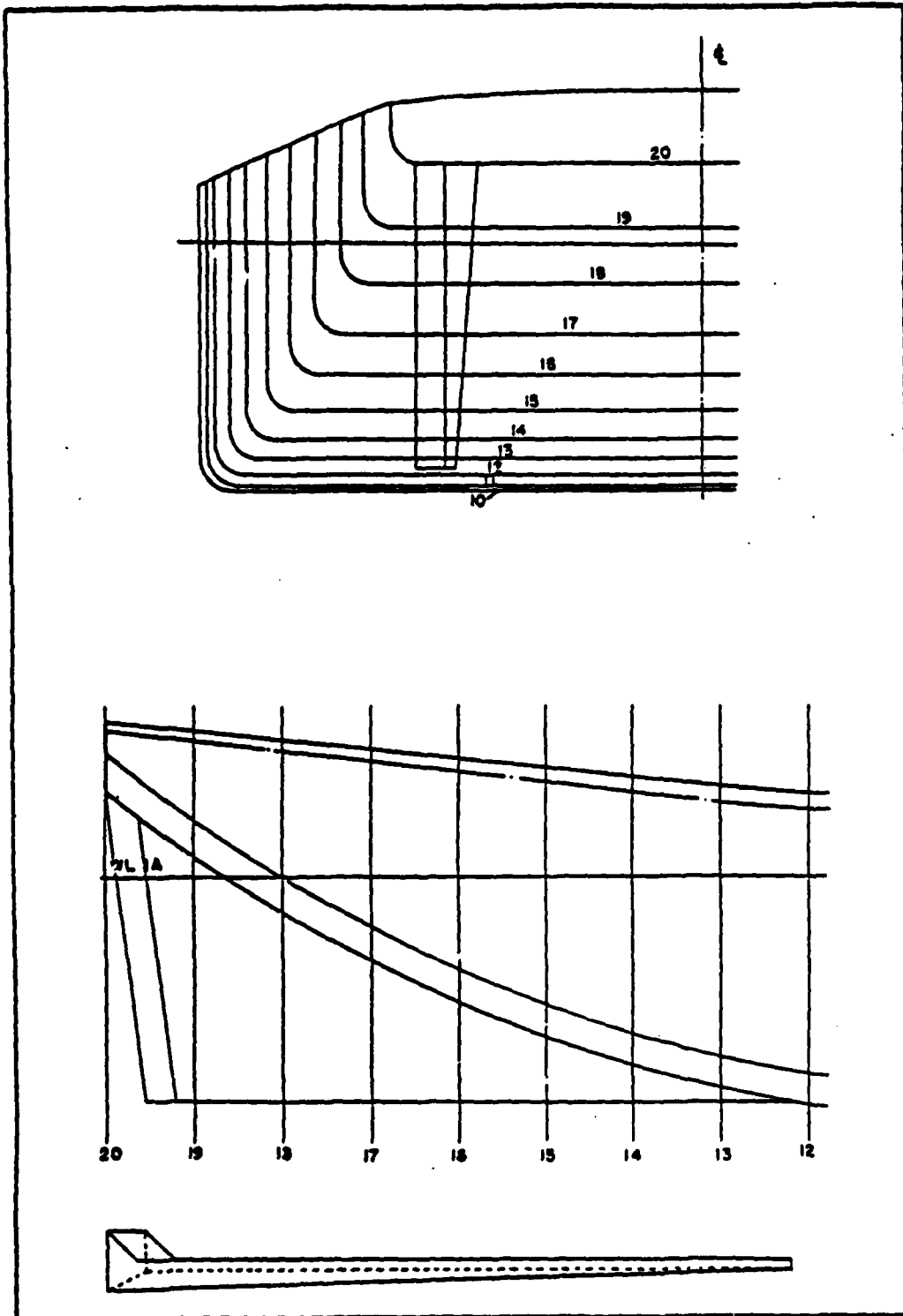


Figure 10C. Design 7003. Skeg revision.

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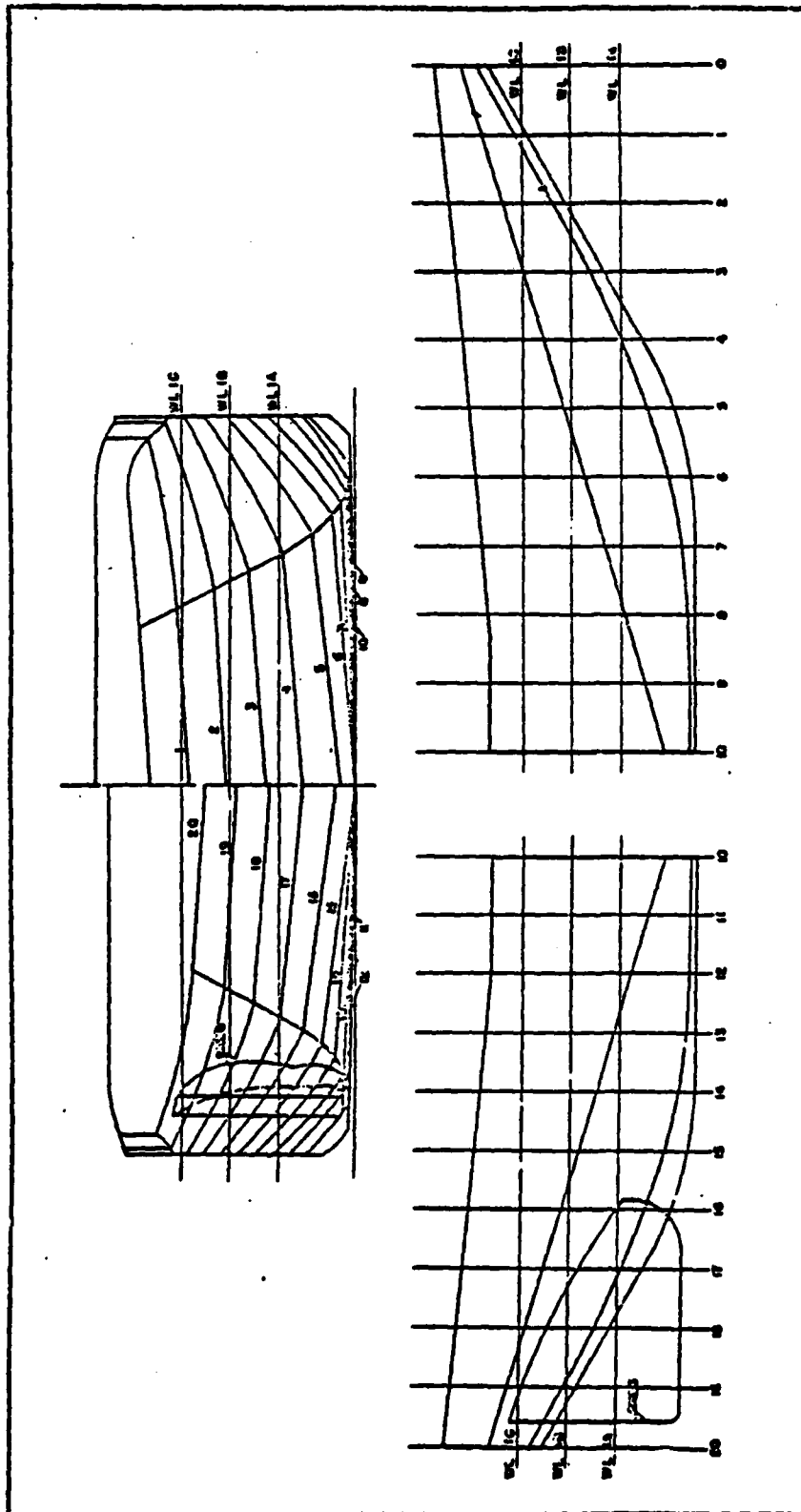


Figure 11A. Design BX 10, 112-foot steel barge. Model lines drawing.

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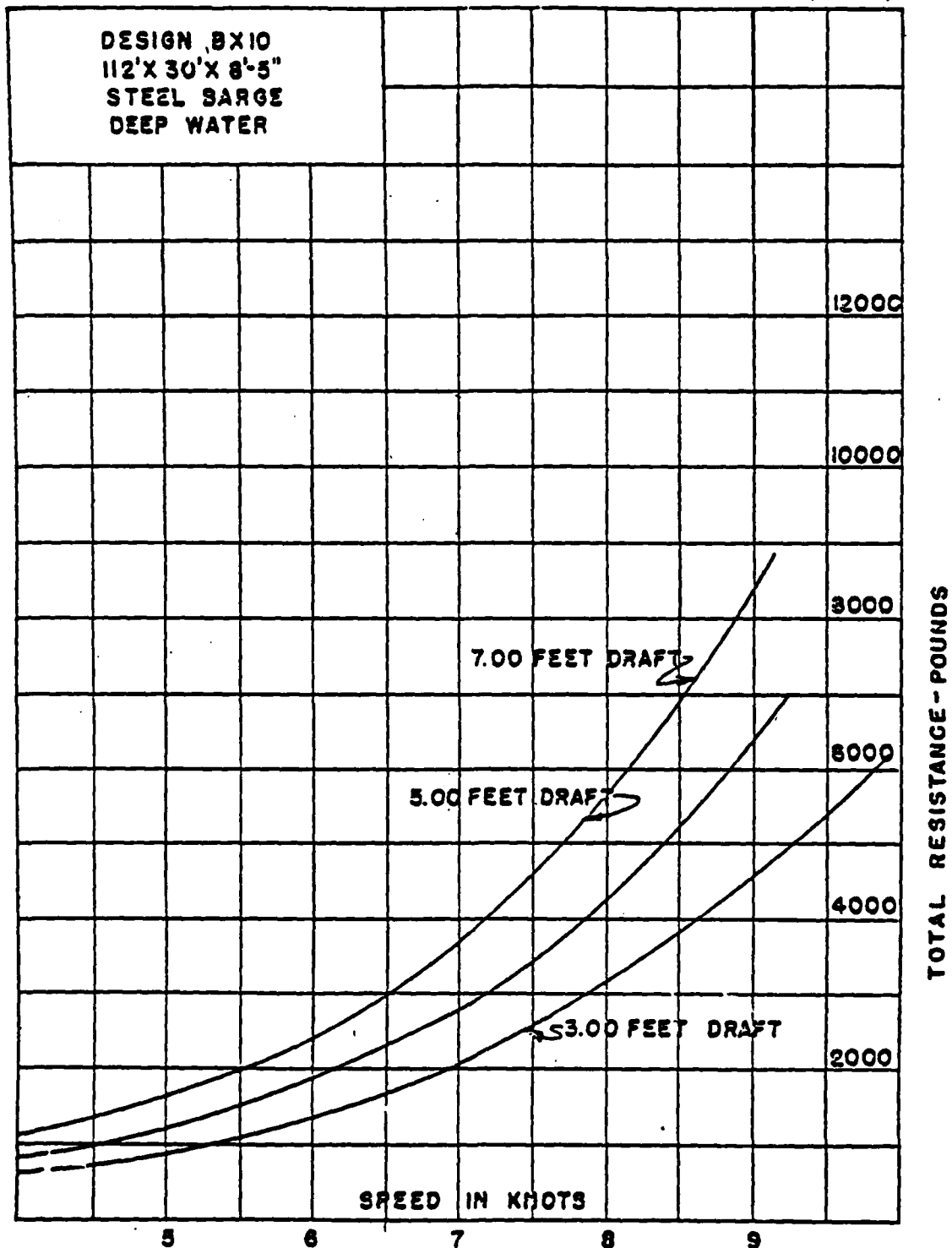


Figure.11B. Design BX 10.- Bare-hull curves of total resistance.

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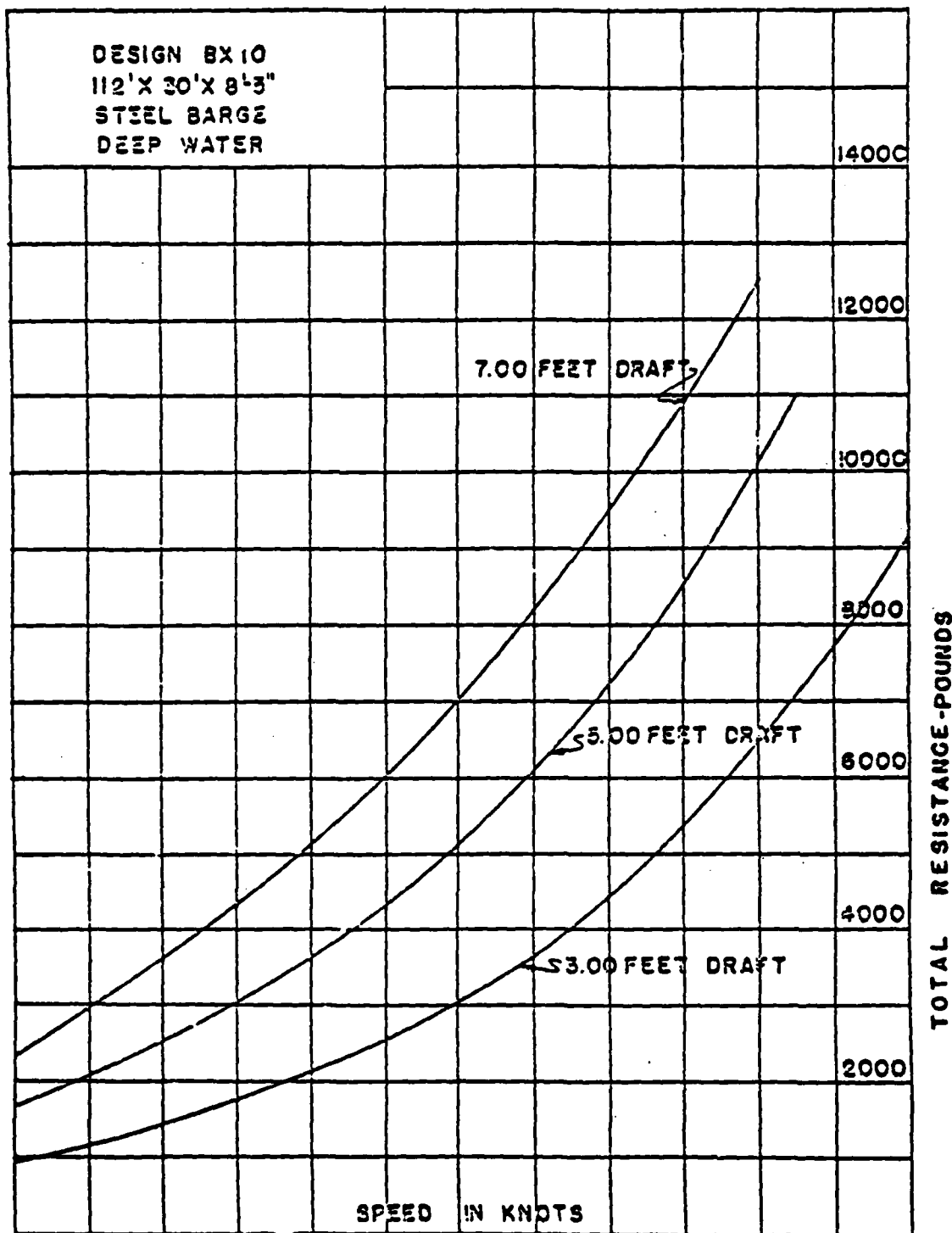


Figure 11C. Design BX 10, with kegs. Curves of total resistance.

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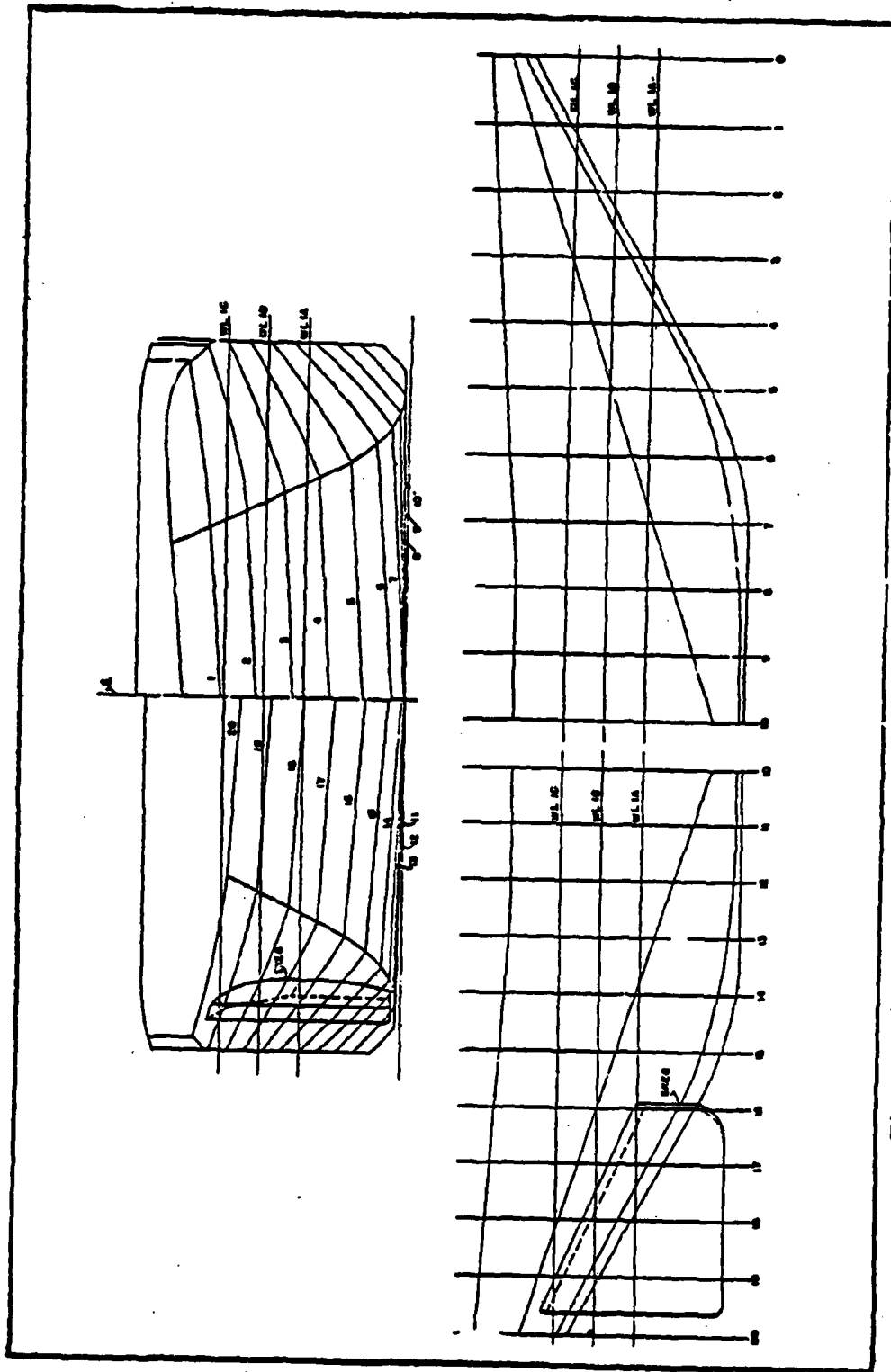


Figure 12A. Design EX 11, 130-foot steel barge. Model lines drawing.

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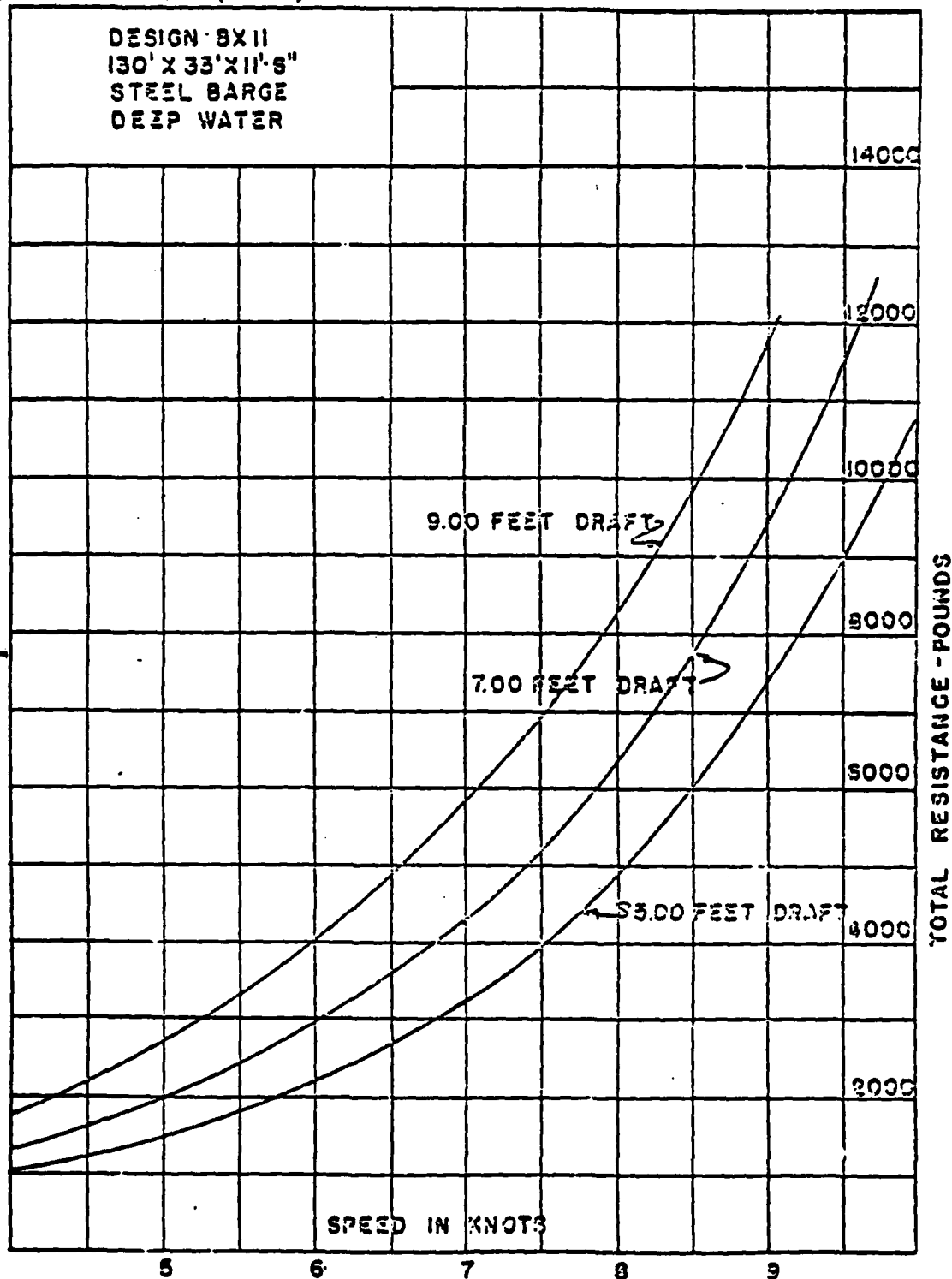


Figure 12B. Design EX 11. Bare-hull curves of total resistance.

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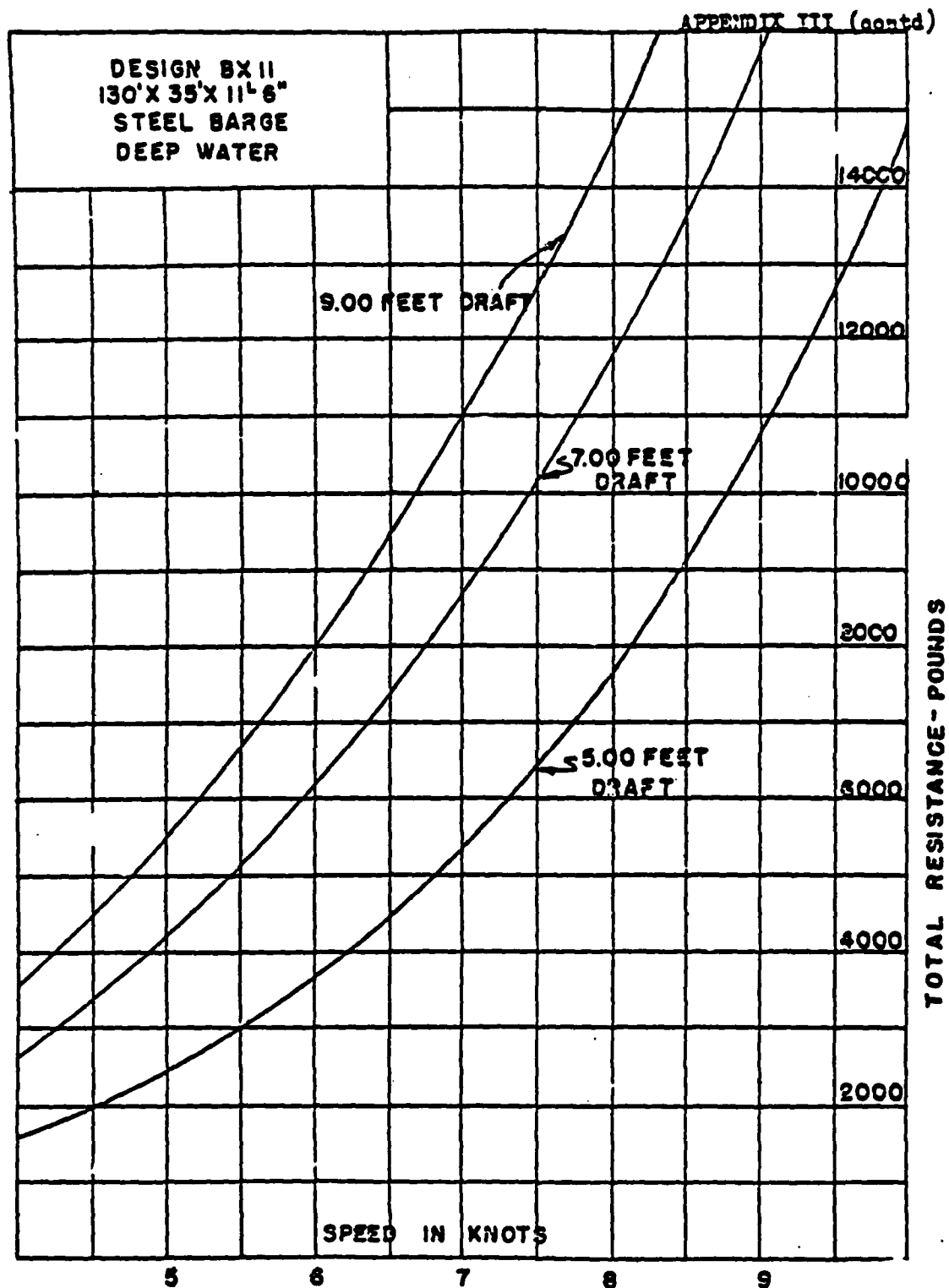


Figure 12C. Design BX 11, with skegs. Curves of total resistance.

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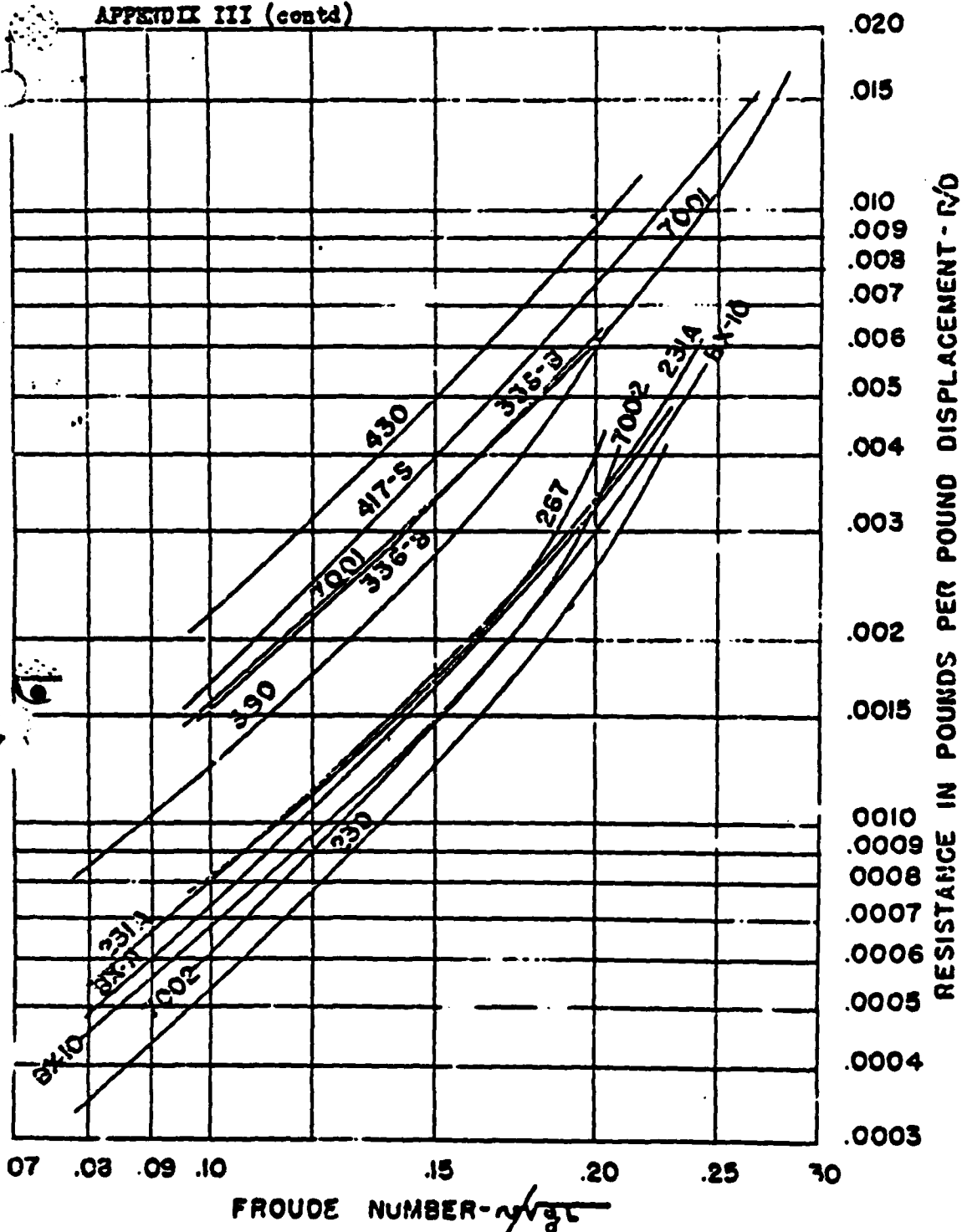


Figure 13. Comparative curves of barge total resistance with yaw uncorrected.

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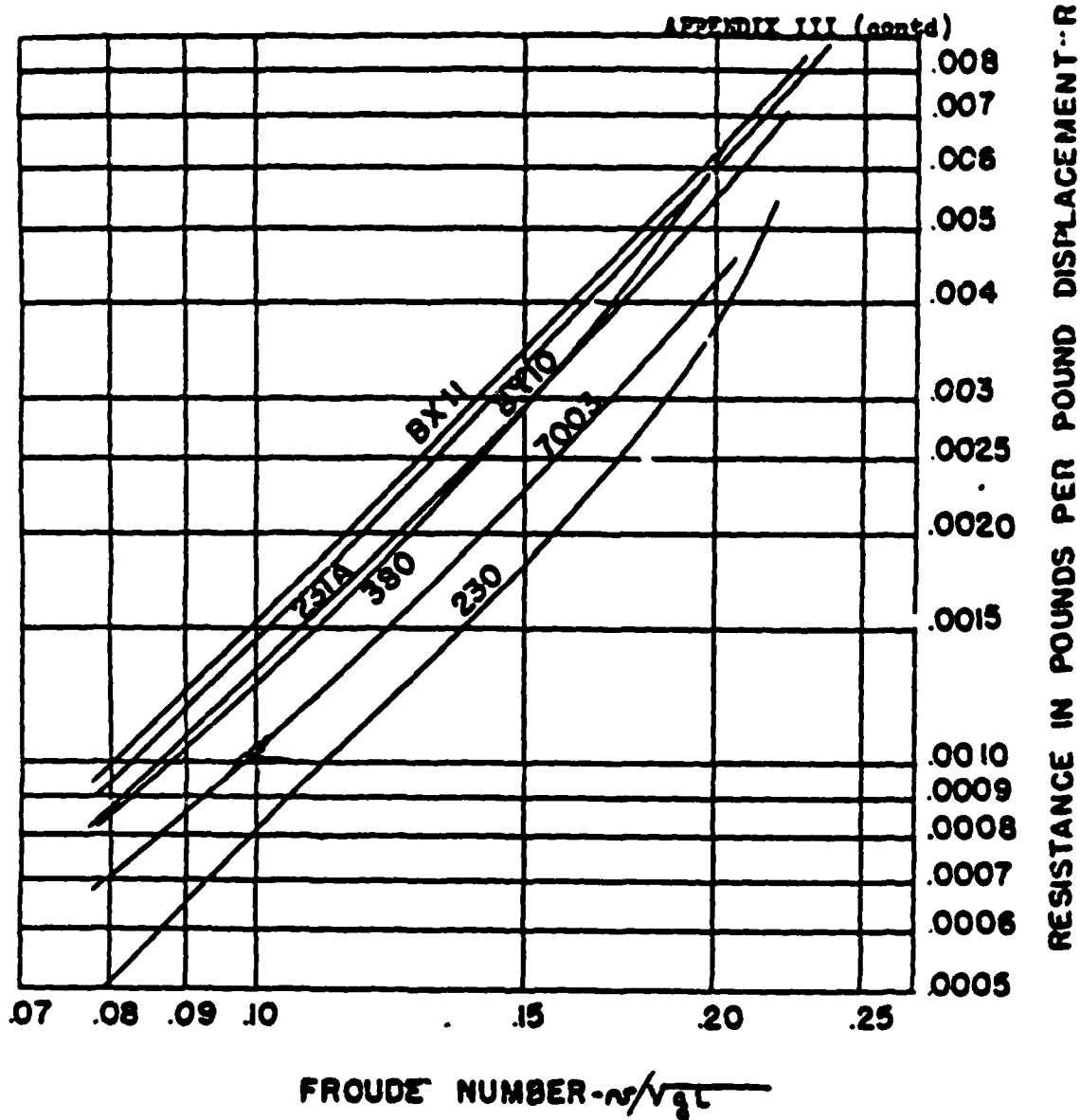


Figure 14. Comparative curves of barge total resistance with yaw corrected.

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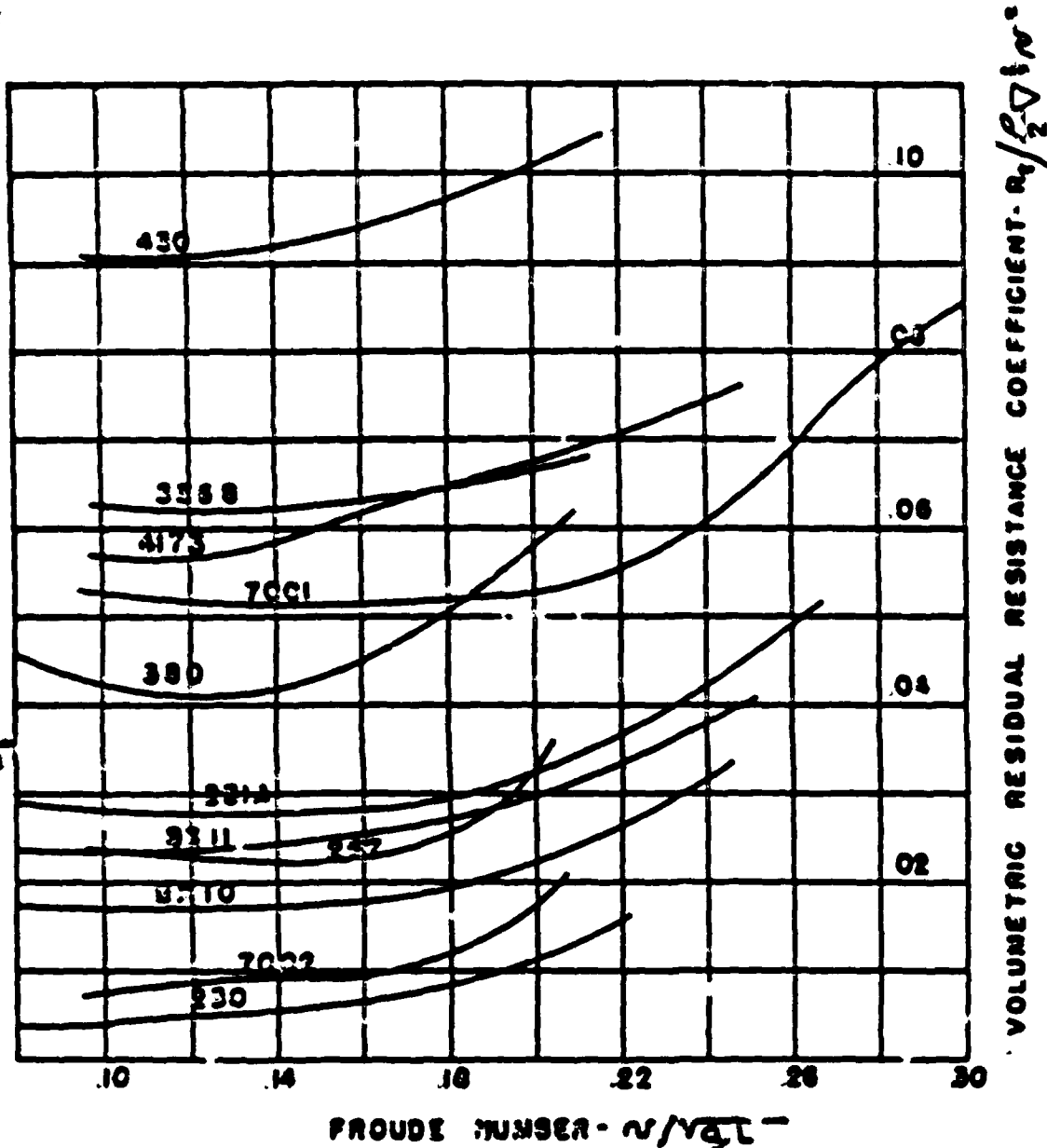


Figure 15. Comparative curves of large residual resistance with and without correction.

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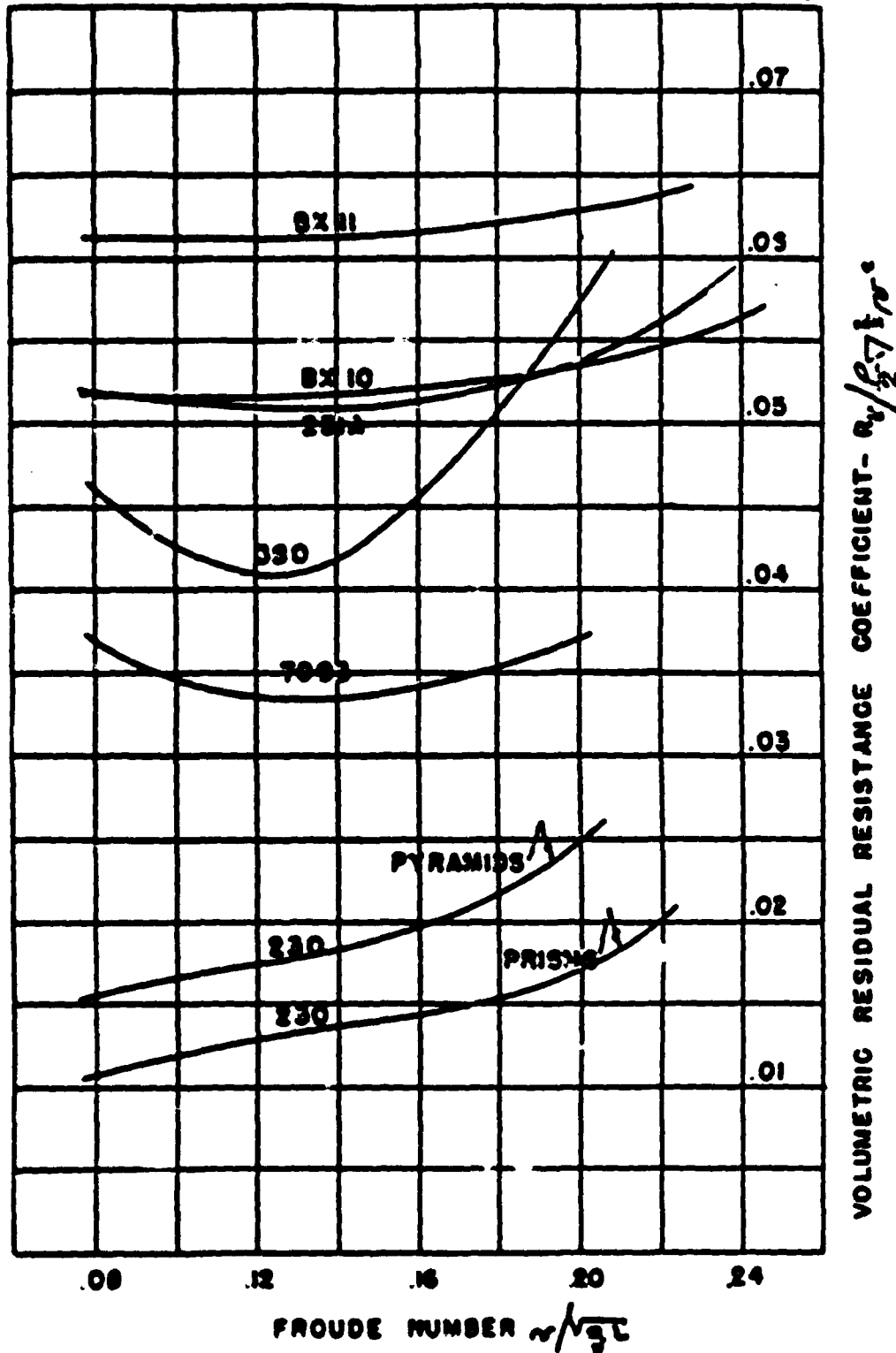


Figure 16. Comparative curves of barge residual resistance with yaw corrected.

APPENDIX III (contd)

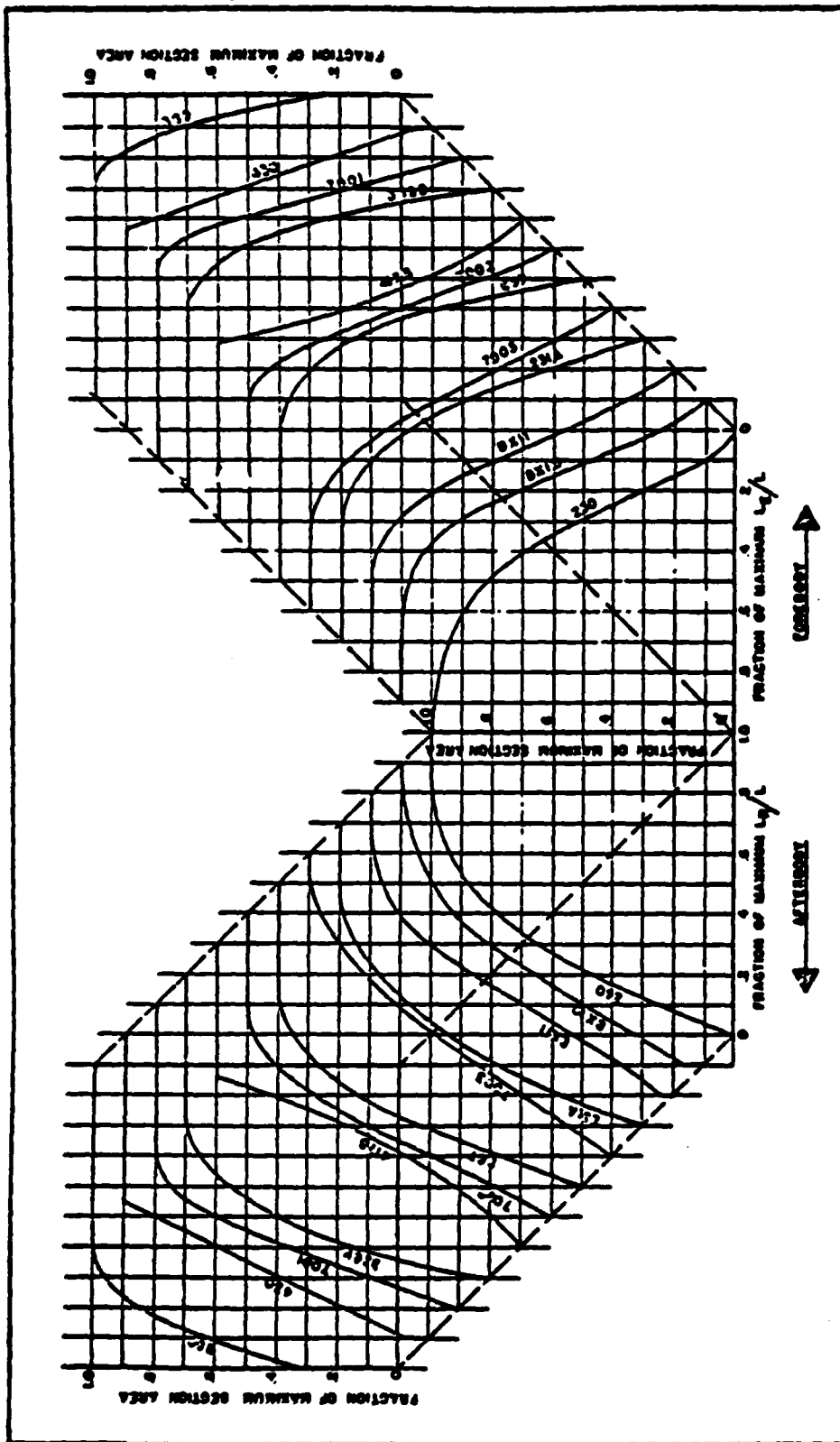


Figure 17. Comparison of sectional-area curves.

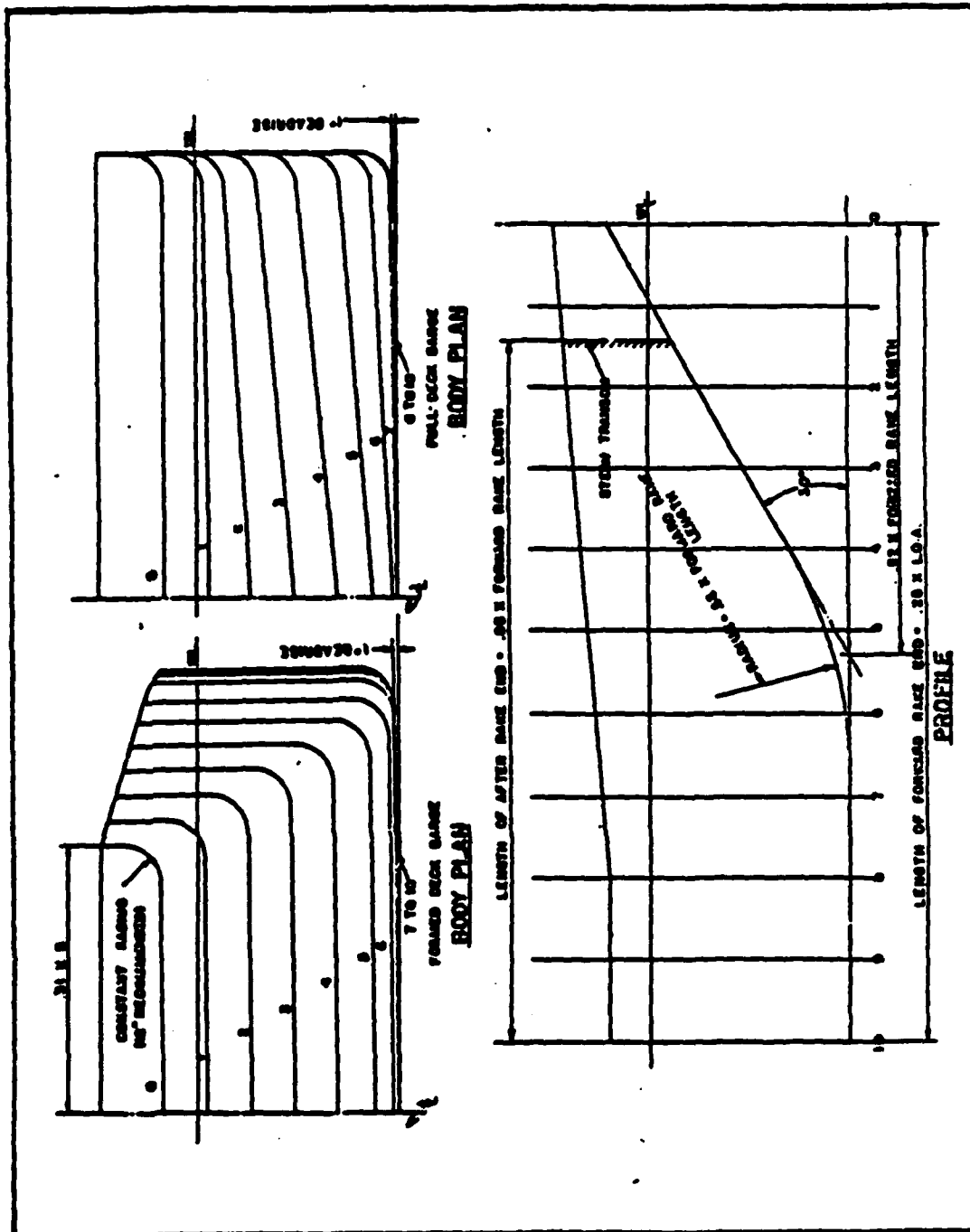


Figure 18A. Recommended standards for formed rake ends. Lines development.

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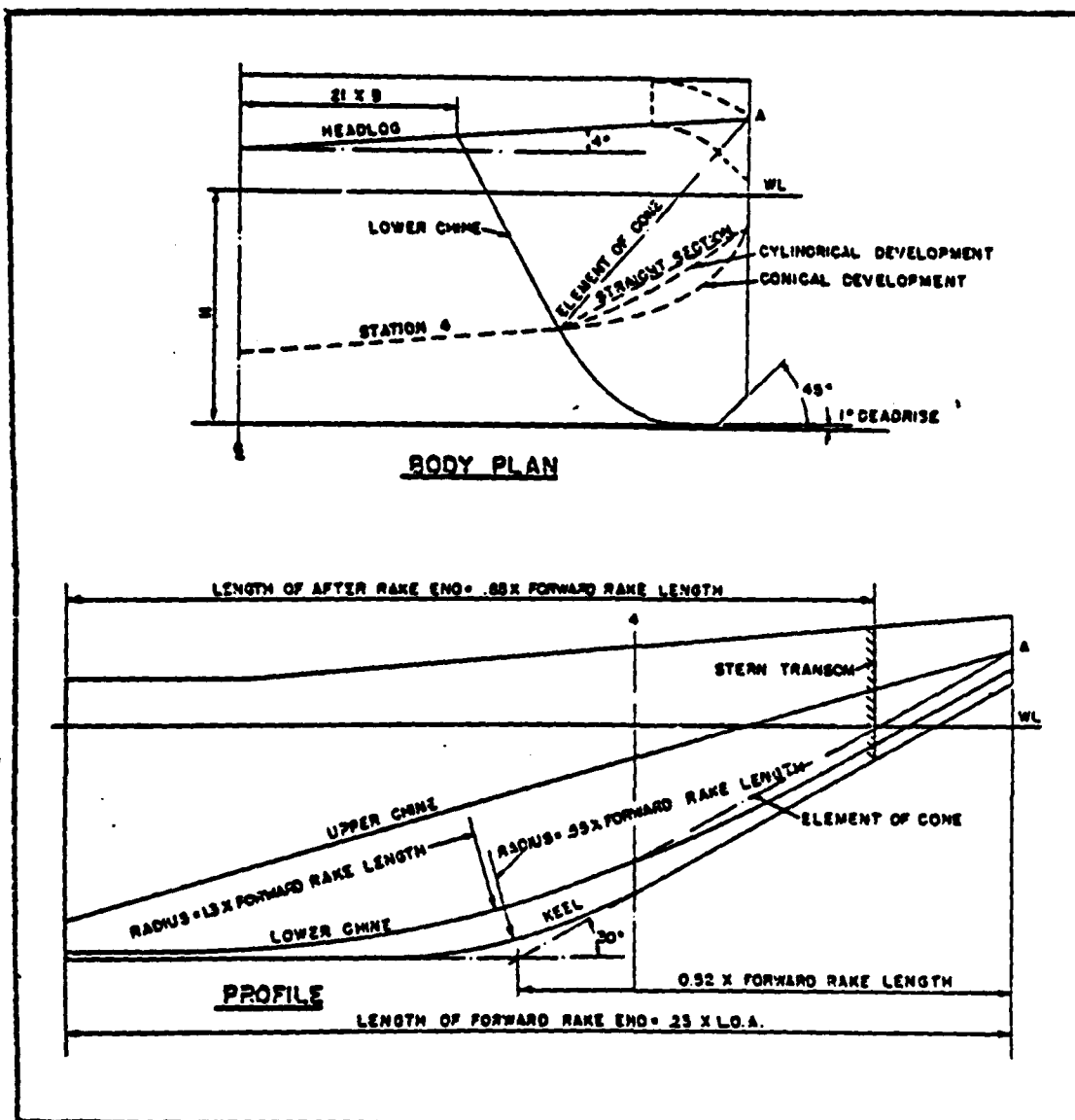


Figure 188. Recommended standard "straight element form." Lines development.

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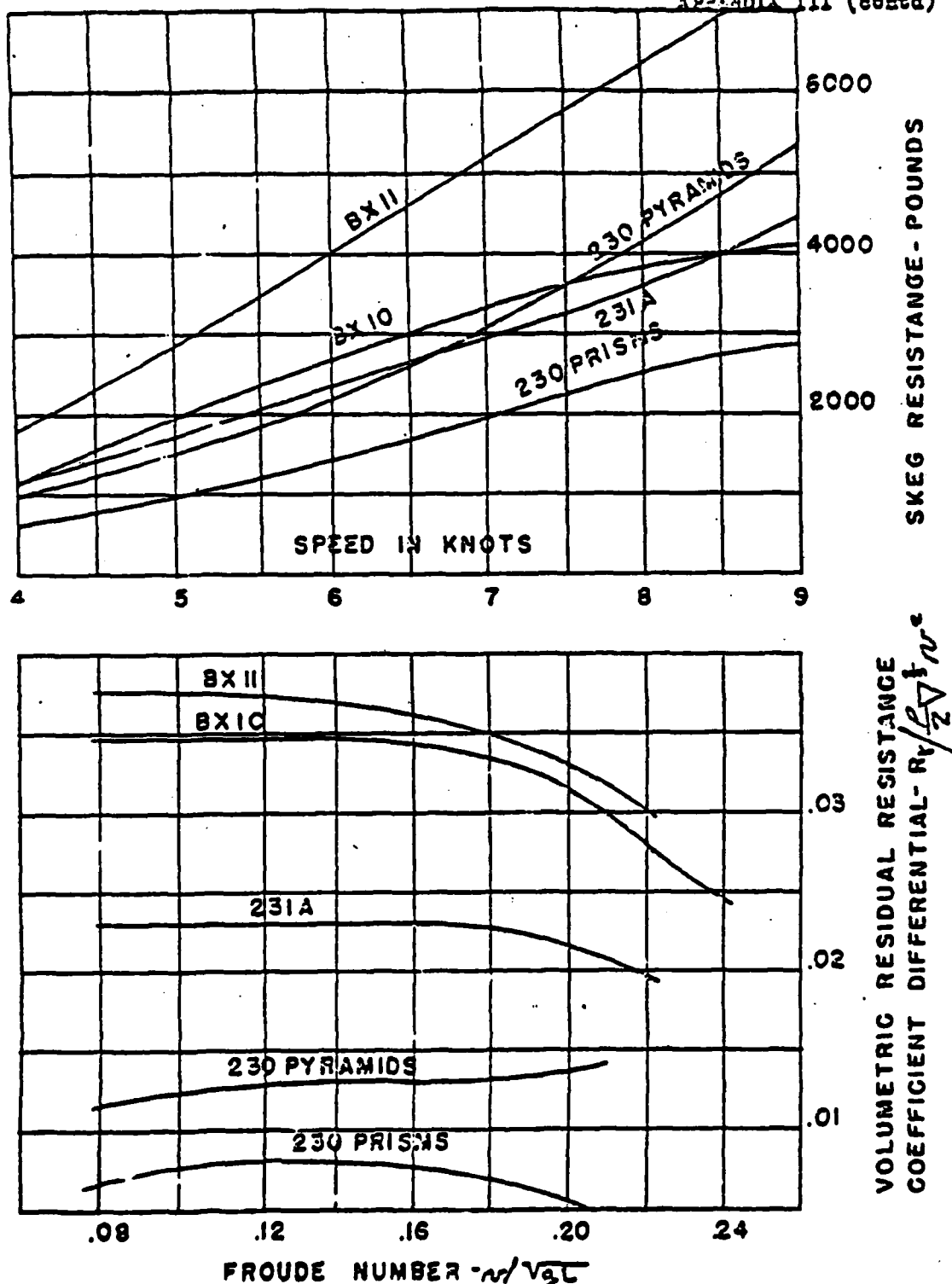


Figure 19. Increase in resistance resulting from yaw-correcting skegs.

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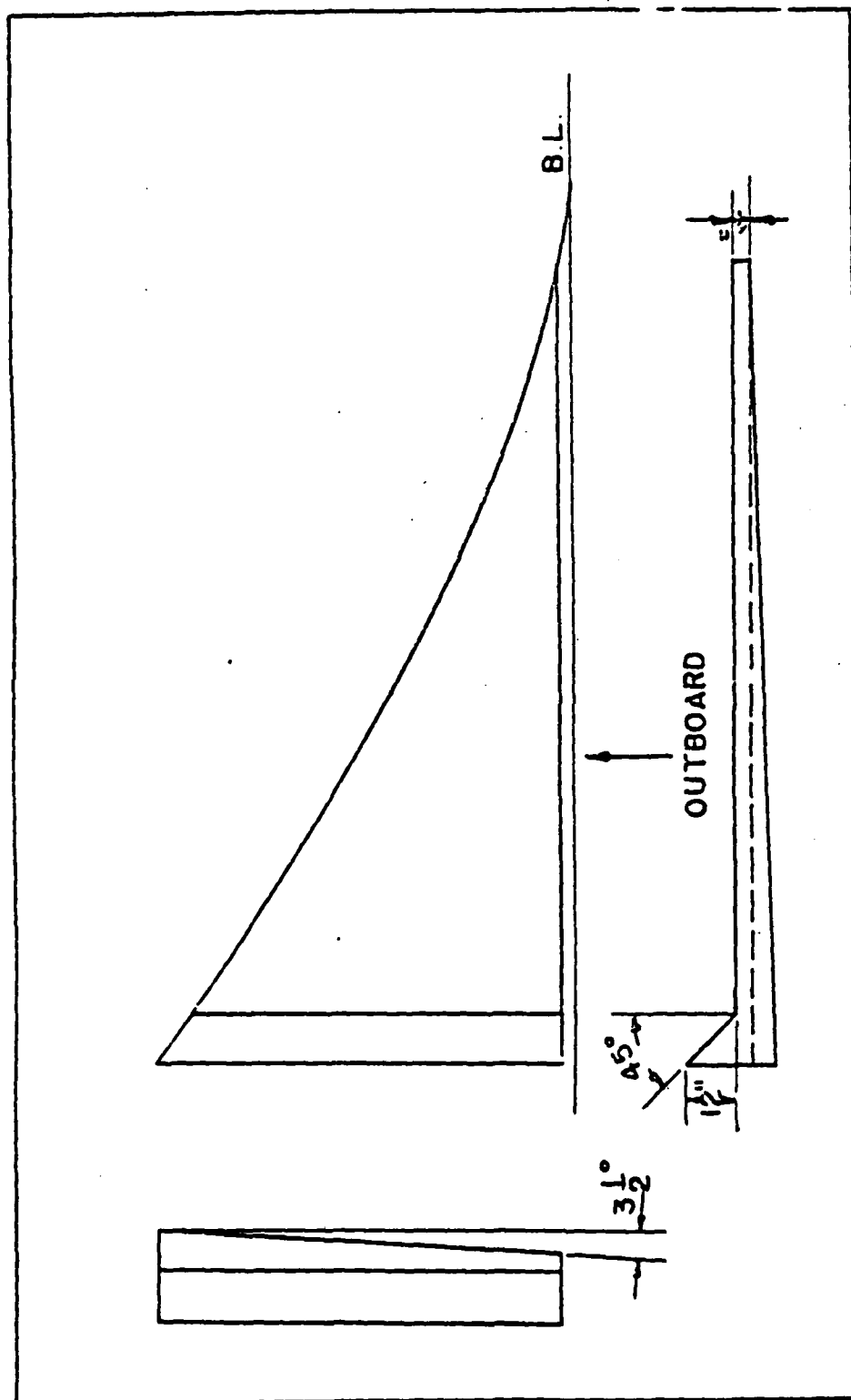


Figure 20. Standard skag development.

APPENDIX IV

Hull-form data and resistance tables

Table	Title
I.	Tabulation of Total Resistances of Barges
II.	Hull-Form Data and Coefficients
III.	Sectional-Area Curves
IV.	Resistance of Barges in Pounds per Pound Displacement, Yaw Uncorrected
V.	Resistance of Barges in Pounds per Pound Displacement, Yaw Corrected
VI.	Volumetric Residual Resistance Coefficients, Yaw Uncorrected
VII.	Volumetric Residual Resistance Coefficients, Yaw Corrected

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APPENDIX V

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- (8) HAY, A.D., AUG. 1948, MARINE ENG. AND SHIPPING REVIEW.
Resistance of Barge Forms With Simple Geometrically Shaped Ends.
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- (10) GERMAN, J.G., AND MC PHERSON, R.P., 1947, UNIVERSITY OF MICHIGAN
Bridle Effect on the Yaw of Towed Barges.

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Transportation Officer, Trieste.	1
Transportation Officer, Eighth Army.	1
Commander-in-Chief Far East.	1
Transportation Officer, Marianas-Bonins Command.	1
Transportation Officer, Ryukyus Command.	1
CO, Bremerhaven Port of Embarkation.	1
ASSISTANT CHIEF OF STAFF, G-4.	5

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NAVAL ARCHITECTS - MARINE ENGINEERS
111 BROADWAY
NEW YORK, 6, NEW YORK

M. ROSENBLATT & SON
MARINE ARCHITECTS - MARINE ENGINEERS
111 BROADWAY
NEW YORK, 6, NEW YORK

FINAL REPORT

1 JUNE 1950

PROJECT 9-57-01-04

HULL FORMS

VOLUME I

BARGE HULL FORM STUDIES

ADST, NEW YORK PORT OF EMBARKATION, BROOKLYN, NEW YORK

RESTRICTED

APPENDIX B

LOCKED PROPELLER DRAG STUDY

Appendix B

The problem of propeller drag was approached by comparing the various available methods of computing locked propeller drag with each other for 2 ships. When possible the rationale was studied for each method in an effort to develop a method which is 'simple' and suitable for all naval ship classes.

Symbols

- R_p = Resistance of 1 propeller (LB.)
- R_{Tp} = Total propeller resistance (LB.)
- R_H = Hull resistance (in calm water w/o propellers) (LB.)
- A_p = Projected area (FT.²)
- A_D = Developed Area (FT.²)
- A_E = Expanded area (FT.²)
- BAR = Blade area ratio
- V = Ship speed Ft./sec.
- V_K = Ship speed KT.
- V_A = Speed of advance
- C_p = Propeller drag coefficient

All of the methods of computing locked propeller drag follow the form $R_p = C_p \rho/2 AV^2$ where A & V may vary depending on the area considered or the units for speed used. To compare various methods of calculation it is useful to reduce the equation above to the form $R_p = KV_K^2$ where K combines C_p , $\rho/2$ (if used), and the appropriate area for each method. The K values are compared by dividing by K for method which corresponds to the equation from Ref. 5. In addition R_{Tp} is calculated for each method and is compared with the calm water hull resistance with the ratio R_{Tp}/R_H .

Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

Section

Prepared by

RCS

Date 10/23/75 Checked

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THE PROBLEM OF PROPELLER DRAG WAS APPROACHED BY COMPARING THE VARIOUS AVAILABLE METHODS OF COMPUTING LOCKED PROPELLER DRAG WITH EACH OTHER FOR 2 SHIPS. WHEN POSSIBLE THE RATIONALE WAS STUDIED FOR EACH METHOD IN AN EFFORT TO DEVELOP A METHOD WHICH IS SIMPLE AND SUITABLE FOR ALL NAVAL SHIP CLASSES.

SYMBOLS

R_p = RESISTANCE OF 1 PROPELLER (LB.)

R_{TP} = TOTAL PROPELLER RESISTANCE (LB.)

R_H = HULL RESISTANCE (IN CALM WATER w/o PROPELLERS) (LB.)

A_p = PROJECTED AREA (FT.²)

A_D = DEVELOPED AREA (")

A_E = EXPANDED AREA (")

BAR = BLADE AREA RATIO

V = SHIP SPEED FT./SEC.

V_K = SHIP SPEED KT.

V_A = SPEED OF ADVANCE

C_p = PROPELLER DRAG COEFFICIENT

ALL OF THE METHODS OF COMPUTING LOCKED PROPELLER DRAG FOLLOW THE FORM $R_p = C_p \frac{1}{2} A V^2$ WHERE A & V MAY VARY DEPENDING ON THE AREA CONSIDERED OR THE UNITS FOR SPEED USED. TO COMPARE VARIOUS METHODS OF CALCULATION IT IS USEFUL TO REDUCE THE EQUATION ABOVE TO THE FORM $R_p = K V_K^2$ WHERE K COMBINES $C_p \frac{1}{2}$ (IF USED), AND THE APPROPRIATE AREA FOR EACH METHOD. THE K VALUES ARE COMPARED BY DIVIDING BY K FOR METHOD WHICH CORRESPONDS TO THE EQUATION FROM REF. 5. IN ADDITION R_{TP} IS CALCULATED FOR EACH METHOD AND IS COMPARED WITH THE CALM WATER HULL RESISTANCE WITH THE RATIO R_{TP} / R_H .

Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

Section

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THE CALM WATER HULL RESISTANCE WITH THE RATIO R_{TP}/R_H .

METHODS OF COMPUTING LOCKED PROPELLER DRAG —
EQUATIONS & REFERENCES

METHOD EQUATION REFERENCES

①

$$R_p = 3.17 A_p V_k^2 \quad 5$$

②

$$R_p = 1.0 \frac{1}{2} A_p V_A^2 \quad \text{OR} \quad 6, 7$$

$$R_p = 1.67 \frac{1}{2} A_p V_A^2$$

③

$$R_p = 1.19 A_p V^2 \quad 8, 9$$

④

$$R_p = \frac{1}{2} \rho V^2 A_B C_p \quad 4$$

WHERE C_p IS FROM FIG. B1

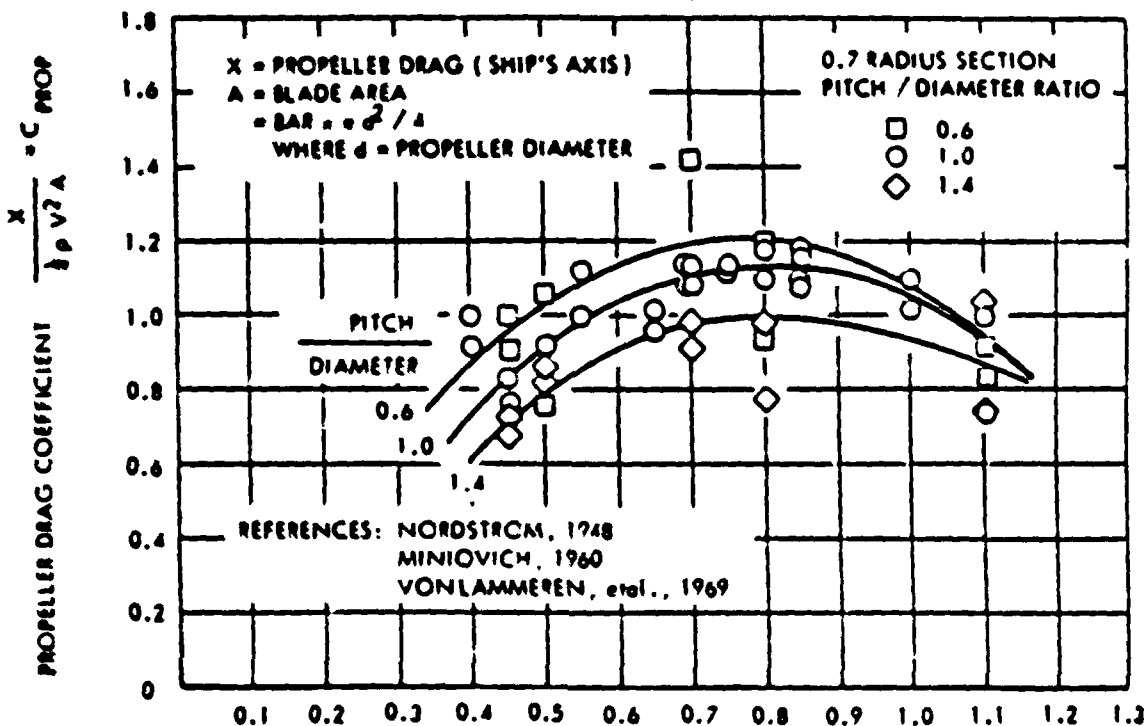


FIG. B-1

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METHOD

EQUATION

REFERENCE

⑤

$$R_p = 1.14 A_D (\frac{1}{2} \rho) V^2 \quad 11$$

COMPARISON OF METHODS FOR 2 SHIPS: LST-1179 & CA 139

SHIP LST-1179 - (SEE SHT. B-4)

METHOD	K	K/K _D	R _{TD} /R _H	
			V _K = 1 KT.	V _K = 12 KT.
①	343	1.0	1.05	1.29
② C _p = 1.0	364	1.06	1.12	1.37
C _p = 1.67	607	1.77	1.86	2.29
③	367.1	1.07	1.13	1.38
④	403.7	1.18	1.25	1.52
⑤	400.	1.17	1.22	1.51

SHIP CA-139 - (SEE SHT. B-6)

①	1037	1.0	1.82	2.19
② C _p = 1.0	1173	1.13	2.06	2.48
C _p = 1.67	1959	1.89	3.44	4.15
③	1111	1.07	1.96	2.36
④	1255	1.21	2.21	2.66
⑤	1278	1.23	2.27	2.73

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Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

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CALCULATIONS FOR LST-1179

PROPELLER CHARACTERISTICS

$DIA. = 11.5$

$PITCH = 12.33'$

$DEVELOPED AREA = 61.488$

$PROJECTED AREA = 54.072$

$\# PROPELLERS = 2$

$BAR = \frac{PROJ. AREA}{DIA.} = 0.633 \quad (EQ. FROM REF. 4)$

$A_E = BAR(103.1) = 65.82$

$V_A = (1-w)V \quad CB = 0.55 \quad w = -0.021 \quad TAYLORS FROM REF. 6$

$= 1.021 V$

$V_A^2 = (1.021)^2 (1.689)^2 V_K^2$

$= 2.973 V_K^2$

$R_H 1KT. = 326$

$V^2 = (1.689)^2 V_K^2 = 2.853 V_K^2$

$R_H 12KT. = 38251$

METHOD 1

$K = 3.17 (54.072)(2) = 343$

$R_{TP} = 343 \quad 1KT.$
 $= 49392 \quad 12KT.$

METHOD 2

$K = 1.0 \left(\frac{1.9905}{2} \right) (61.488)(2)(2.973) = 364$

OR
 $K = 1.67 \left(\frac{1.9905}{2} \right) (61.488)(2)(2.973) = 607$

$R_{TP} = 364 \quad (1KT.) \quad OR \quad 607$

$R_{TP} = 52416 \quad OR \quad 87408 \quad AT \quad 12KT.$

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Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

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METHOD 3

$$K = 1.19 (54.072)(2)(1.689)^2 = 367.1$$

$$R_{TP} = 367.1 \quad 1 \text{ KT.}$$

$$= 52865 \quad 12 \text{ KT.}$$

METHOD 4

$$K = \frac{1}{2} (1.9905)(1.08)(65.82)(2)(1.689)^2 = 403.6$$

$$C_p = 1.08$$

$$R_{TP} = 404 \quad 1 \text{ KT.}$$

$$= 58125 \quad 12 \text{ KT.}$$

METHOD 5

$$K = 1.14 (A_D)(2)(2.853) = 379.96$$

$$R_{TP} = 400 \quad (1 \text{ KT.})$$

$$R_{TP} = 57600 \quad (12 \text{ KT.})$$

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No. 3419
Sheet B-6 of

Subject PROPELLER DRAG STUDY

Ship or Project TOWING RESISTANCE CRITERIA

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CALCULATIONS FOR CA - 139

PROPELLER CHARACTERISTICS

DIA. = 12.66

PITCH = 13.16

$A_D =$

$A_P = 81.82$

PROP. = 4

BAR = $\frac{A_P}{D.A.}$

$1.067 - 0.229 \left(\frac{13.16}{12.66} \right) = 0.784$

$R_H = 568 \text{ lb. 1 KT.}$

$R_H = 67917 \text{ lb. 12 KT.}$

$A_E = \text{BAR} (125.9) = 98.69$

$C_B = 0.543$

$W = -0.023 \text{ (TAYLORS REF. 6)}$

$V_A = (1 - W) V = 1.023 V$

$V_A^2 = (1.023)^2 (1.689)^2 V_K^2 = 2.985 V_K^2$

$V^2 = 2.853 V_K^2$

METHOD 1

$K = 3.17 (81.82) (4) = 1037$

$R_{TP} = 1037 \text{ 1 KT.}$

$= 149396 \text{ 12 KT.}$

METHOD 2

$C_p = 1.0 \quad K = 1.0 \left(\frac{1.9905}{2} \right) (98.69) (2.985) (4) = 1173$

$C_p = 1.67 \quad K = 1959$

$C_p = 1.0$

$R_{TP} = 1173 \text{ (1 KT.)}$

OR

$C_p = 1.67$

1959 (1 KT.)

$= 168912 \text{ (12 KT.)}$

OR

282096 (12 KT.)

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METHOD 3

$$K = 1.19 A_p (4) (2.853) = 1111$$

$$R_{TP} = 1111 \quad 1 \text{ KT.}$$

$$= 16000.3 \quad 12 \text{ KT.}$$

METHOD 4

$$K = \frac{1}{2} (1.9905) (2.853) (1.12) (4) (98.7)$$

$$= 1255 \quad C_p = 1.12 \quad \text{FROM fig. B-1}$$

$$R_{TP} = 1255 \quad 1 \text{ KT.}$$

$$= 18080 \quad 12 \text{ KT.}$$

METHOD 5

$$K = 1.14 (98.7) (\frac{1}{2}) (1.9905) (4) (2.853)$$

$$= 1278$$

$$R_{TP} = 1278 \quad (1 \text{ KT.})$$

$$= 18403.2 \quad (12 \text{ KT.})$$

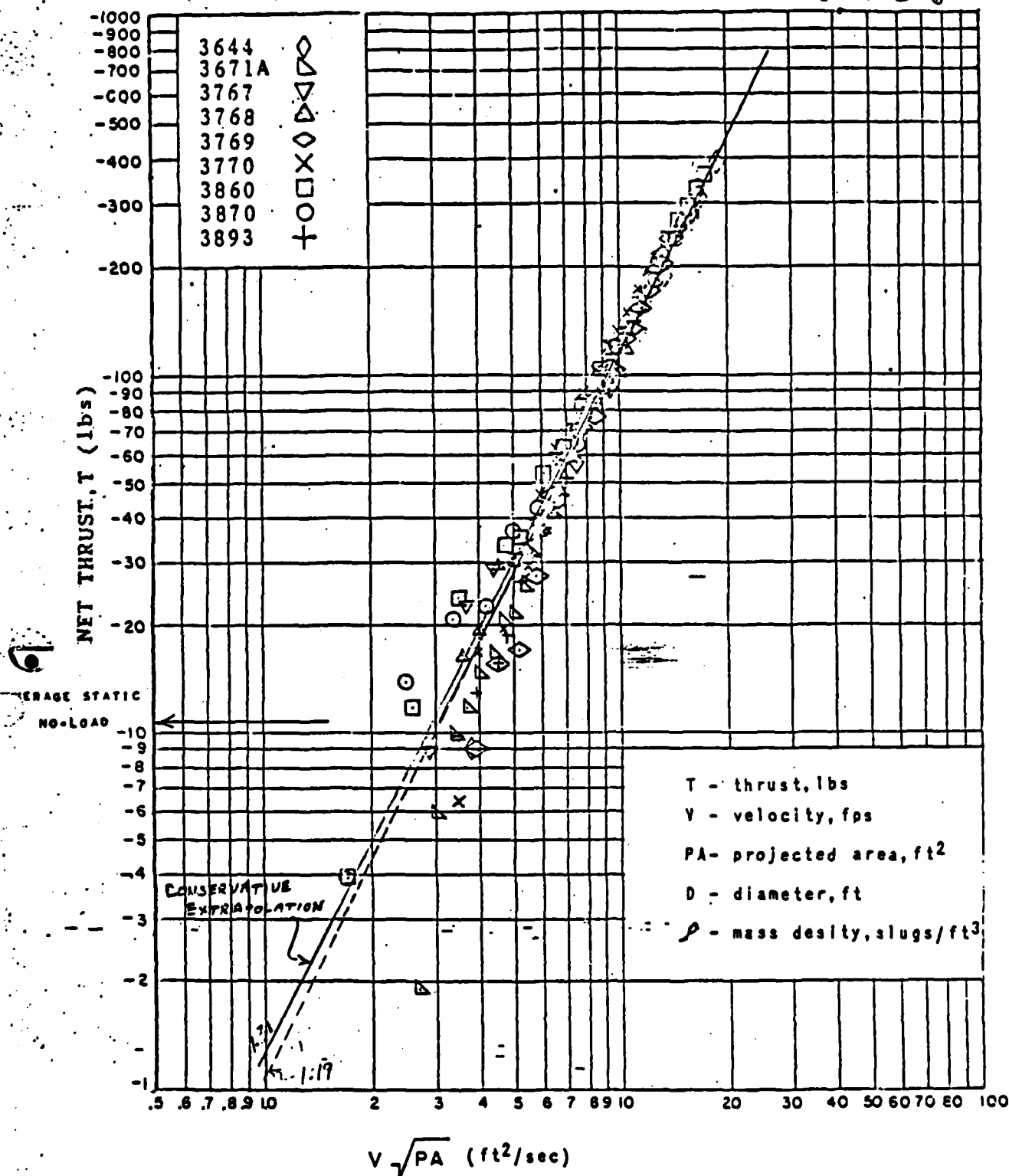
CONCLUSIONS

IF THE COEFFICIENT OF 1.19 IN METHOD 3 IS INCREASED BY 10% TO GIVE $C_p = 1.31$ THEN METHODS 3, 4 & 5 WILL GIVE CLOSE AGREEMENT. AS SEEN IN Figure B-2 THIS PRODUCES A SMALL CHANGE OF SLOPE FOR THE LINE WHICH GIVES A COEFFICIENT OF 1.19. BECAUSE THE DATA DOES SHOW SCATTER IN THE AREA OF INTEREST, SOME CONSERVATISM IS CALLED FOR.

FINAL EQUATION FOR PROPELLER DRAG

$$R_p = 1.31 A_p V^2 \quad \text{OR} \quad R_p = 1.31 (2.853) A_p V_K^2$$

SHT. B-8



4 B-2

Figure 11 - Thrust Developed by Nonrotating Propellers

B-2.

APPENDIX C

CALCULATIONS FOR ADDED RESISTANCE IN WAVES

Appendix C

As with Appendix A the unabridged report contains all of the detailed calculations (sheets 1-57) while the abridged report contains only sample calculations. The added resistance in waves is calculated by two methods. The first is very approximate and utilizes a formula derived by Jacobs and Lewis for a stationary ship in waves. This serves as a rough check for the second method which utilizes the seakeeping tables of reference 22.

List of Ships and in Study

Number of Added Resistance Curve (See Fig.4&5)	Ship Class	Sheet number for Detailed Calculations
1	MSO-422	2
2	ATF-148	9
3	CGN-25	16
4	FF-1040	22
5	AOR-1	28
6	AOE-1	34
7	CA-139	40
8	AF-58	46
9	LST-1179	51

Subject ADDED RESISTANCE FOR SEA STATEShip or Project TOWING RESISTANCESection _____ Prepared by RCS Date 2/20/76 Checked _____ Reviewed _____

The calculation below compares the added resistance in waves obtained from the formula of Jacobs and Lewis with the seakeeping standard series. The formula of Jacobs and Lewis is applicable for stationary ships in short waves where resistance due to pitching and heaving is assumed negligible. The authors of the seakeeping standard series have stated the added resistance calculated will generally be high for low Froude numbers and for long waves. Because the lowest non-dimensional seastate ratio is 0.015, the larger ships have no added resistance values calculated for Beaufort numbers below 5 so correlation is conducted for a significant wave height of 5.0 FT. TO CHECK the extrapolation of the data.

FORMULA DERIVED BY JACOBS & LEWIS:

$$R = 0.174 g p \left(\frac{1}{2} \right)^{1.67} (\sin \alpha)^{0.33} B^{1.33}$$

 $\alpha = \frac{1}{2}$ ANGLE OF MEAN WATERLINE, h = WAVE HEIGHT

SHIP No.	SHIP	STB. WAVE HEIGHT FT. (h)	BEAM (B) FT.	α (ASSUMED) DEG.	RESIS. R LB.	STD. SERIES RESIS. LB.
1	MSO 422	5.0	34.6	7°	2843	2700
2	ATF 148	"	44.9	9°	4421	3650
3	CGN 25	"	56.66	10°	6166	1800
4	FF 1040	"	44.2	8°	4166	1800
5	AOR-1	"	96.0	10°	12604	4000
6	AOE-1	"	107	6°	12300	4000
7	CA 139	"	75.4	9°	8822	4000
8	AF 58	"	72.0	10°	8590	4000
9	LST 1179	"	68.0	10°	7960	4000

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DESIGN CALCULATION SHEET

No. 3419
Sheet 2 of 57

Subject ADDED RESISTANCE FOR SEA STATE - MSO 422

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RCS Date 11/11/75 Checked _____ Reviewed _____

CALCULATIONS FOR SHIP MSO-422

FOR ALL CALCULATIONS THE FOLLOWING RELATIONSHIPS APPLY:

$$LBP/LWL = 0.983 \text{ (ASSUMED)}$$

$$L = LBP = 0.983 (165.2) = 162.39$$

$$\text{FROUDE No. OF } 0.10 = 4.32 \text{ KT.}$$

$$B/T = 3.295, \quad L/B = 4.693 \quad CB = 0.522$$

$$B/T^+ = 4.0$$

$$B/T^- = 3.0$$

$$L/B^+ = 7.0$$

$$L/B^- = 5.5$$

$$CB^+ = 0.60$$

$$CB^- = 0.55$$

$$\text{CALM WATER RESISTANCE AT } 4.32 \text{ KT.} = 1162 \text{ LB.}$$

$$\text{MULTIPLIER} = \frac{99 (LBP)^3}{10^7} = 27.425$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.10	2.44	11.96	27.425	328	1162	1.28
2	0.10	4.06	68.93	"	1890	"	2.63
3	0.10	3.24	36.50	"	1001	"	1.86
4	0.10	12.18	279.5	"	7665	"	7.60
5	0.10	6.5	166.2	"	4558	"	4.92

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DESIGN CALCULATION SHEET

No. 3419
Sheet 3 of 57

Subject ADDED RESISTANCE FOR SEA STATE - MSC422

Ship or Project TOWING RESISTANCE

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CALCULATION #1

Froude # = 0.10 (4.32 KT.)

SEA STATE = 0.015 $H^{1/3} = 2.44$ FT.

$F^+ = 0.15$

$F^- = 0.10$

$S^+ = 0.020$

$S^- = 0.015$

CALCULATION #2

Froude # = 0.10

SEA STATE = 0.025 $H^{1/3} = 4.06$ FT.

$F^+ = 0.15$

$F^- = 0.10$

$S^+ = 0.030$

$S^- = 0.025$

CALCULATION #3

Froude # = 0.10

SEA STATE = 0.02 $H^{1/3} = 3.24$

$F^+ = 0.15$

$F^- = 0.10$

$S^+ = 0.025$

$S^- = 0.02$

CALCULATION #4

Froude # = 0.10

SEA STATE = 0.075 $H^{1/3} = 12.18$ FT.

$F^+ = 0.15$

$F^- = 0.10$

$S^+ = 0.10$

$S^- = 0.075$

CALCULATION #5

Froude # = 0.10

SEA STATE = 0.04 $H^{1/3} = 6.50$

$F^+ = 0.15$

$F^- = 0.10$

$S^+ = 0.050$

$S^- = 0.040$

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DESIGN CALCULATION SHEET

CALCULATION #1

No. 3419

Sheet 4 of 57

Subject ADDED RESISTANCE FOR SEA STATE - IASO 422

Ship or Project EIMER. TAILING GEAR

Section

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#1		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-(B/T)^*} = 0.295$	$\frac{4/B-4/B^*}{4/B^*-4/B^*} = -0.53$	$\frac{CB-CB^*}{CB^*-CB^*} = -0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	11	11				
2	9		11			
3	32	32				
4	32			11.59		
5	13	13				
6	12		13			
7	34	34				
8	34				12.13	
9	10	10				
10	9		10			
11	25	25				
12	27			10.59		
13	12	12				
14	11		12			
15	27	27				11.96
16	28					
17	11	11				
18	9		11			
19	32	32				
20	32			11.89		
21	14	14				
22	12		14			
23	35	35				
24	35				12.43	
25	10	10				
26	9		10			
27	26	26				
28	27			10.89		
29	13	13				
30	12		13			
31	29	29				
32	9					

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DESIGN CALCULATION SHEET

CALCULATION #2

No. 3419

Sheet 5 of 57

Subject ADDED RESISTANCE FOR SEA STATE - MSC 422

Ship or Project EMER. TOWING GEAR

Section

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#2		$\frac{F-F'}{F'-F} = 0$	$\frac{S-S'}{S'-S} = 0$	$\frac{(B/T)-(B'/T')}{B/T - B'/T'} = 0.275$	$\frac{4/B - 4/B'}{4/B - 4/B'} = 0.5$	$\frac{CB - CB'}{CB + CB'} = 0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	61	61				
2	65		61			
3	91	91				
4	103			60.705		
5	60	60				
6	65		60			
7	89	88				
8	99				69.69	
9	44	44				
10	51		44			
11	63	63				
12	76			44		
13	44	44				
14	49		44			
15	63	63				
16	71					68.93
17	62	62				
18	66		62			
19	95	95				
20	106			62.59		
21	64	64				
22	67		64			
23	94	94				
24	103				71.04	
25	46	46				
26	53		46			
27	67	67				
28	78			46.88		
29	49	49				
30	52		49			
31	67	69				
32	76					

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DESIGN CALCULATION SHEET

CALCULATION # 3

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Subject ADDED RESISTANCE FOR SEA STATE - MSO 422Ship or Project EMER. TOWING GEAR

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#3		$\frac{F-F'}{F'-F''} = 0$	$\frac{S-S'}{S'-S''} = 0$	$\frac{(\frac{1}{T}) - (\frac{1}{T'})}{\frac{1}{T'} - \frac{1}{T''}} = 0.295$	$\frac{\frac{1}{B} - \frac{1}{B'}}{\frac{1}{B'} - \frac{1}{B''}} = 0.555$	$\frac{CB - CB'}{CB' - CB''} = 0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED $\frac{1}{T}$	FOR DESIRED $\frac{1}{B}$	FOR DESIRED CB
1	32	32				
2	32		32			
3	61	61				
4	65			32.59		
5	34	34				
6	34		34			
7	60	60				
8	65				36.36	
9	25	25				
10	27		25			
11	41	44				
12	51			25.59		
13	27	27				
14	28		27			
15	44	44				36.50
16	49					
17	32	32				
18	32		32			
19	62	62				
20	66			32.885		
21	35	35				
22	35		35			
23	64	64				
24	67				36.11	
25	26	26				
26	27		26			
27	46	46				
28	52			26.885		
29	29	29				
30	29		29			
31	49	49				
32	52					

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DESIGN CALCULATION SHEET

CALCULATION # 4

No. 3419

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Subject ADDED RESISTANCE FOR SEA STATE - 1450 422

Ship or Project EMER. TAILING GEAR

Section

Prepared by RCS

Date 12/10/75

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		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{B/T - 4/F} = 0.295$	$\frac{4/B - 4/B^*}{4/B^* - 4/B} = 0.538$	$\frac{CB - CB^*}{CB^* - CB} = -0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROM NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	248	248				
2	332		248			
3	282	282				
4	405			243		
5	231	231				
6	305		231			
7	262	262				
8	377				289.5	
9	158	158				
10	217		158			
11	178	178				
12	262			156.53		
13	153	153				
14	203		153			
15	172	172				
16	250					279.48
17	263	263				
18	352		263			
19	300	300				
20	434			260.1		
21	253	253				
22	331		253			
23	289	289				
24	418				307.4	
25	172	172				
26	233		172			
27	194	194				
28	285					
29	173	173		172.3		
30	222		173			
31	195	195				

DESIGN CALCULATION SHEET

CALCULATION #5

No. 3417

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Subject ADDED RESISTANCE FOR SEA STATE - MSO 422Ship or Project TOWING RESISTANCE

Section

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Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T) - (B/T)^-}{(B/T)^+ - (B/T)^-} = 0.295$	$\frac{4/B - 4/B^-}{4/B^+ - 4/B^-} = -0.538$	$\frac{CB \cdot CB^-}{CB^+ \cdot CB^-} = -0.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRIDGE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	148	148				
2	175		148			
3	191	191				
4	234			145.6		
5	140	140				
6	161		140			
7	179	179			171.1	
8	214					
9	99	99				
10	120		99			
11	124	124				
12	157			98.11		
13	96	96				
14	112		96			
15	120	120				166.2
16	146					
17	155	155				
18	181		155			
19	201	201				
20	244			154.11		
21	152	152				
22	172		152			
23	194	194				
24	230				179.8	
25	106	106				
26	128		106			
27	134	134				
28	166			106.30		
29	107	107				
30	122		107			
31	135	135				
32	160					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 9 of 57

Subject ADDED RESISTANCE FOR SEA STATE - ATF 148

Ship or Project TOWING RESISTANCE

Section _____ Prepared by PCS Date 2/3/76 Checked _____ Reviewed _____

CALCULATIONS FOR ATF 148

$$LBP/LWL = 0.983 \quad (\text{ASSUMED})$$

$$L = LBP = 0.983(224) = 220.19$$

$$\text{Froude No. FOR 12 KT.} = \frac{12 \times 1.689}{\sqrt{32.174 \times 224}} = 0.238$$

$$\text{USE FR. NO.} = 0.15 \equiv 7.54 \text{ KT.}$$

$$B/T = 2.85, \quad 4/B = 4.99, \quad CB = 0.459$$

$$\begin{array}{ll} B/T^+ = 3.0 & B/T^- = 2.0 \\ 4/B^+ = 7.0 & 4/B^- = 5.5 \\ CB^+ = 0.60 & CB^- = 0.55 \end{array}$$

STILL WATER RESISTANCE AT 7.54 KT. = 7654 LB.

$$\text{MULTIPLIER} = \frac{99 (LBP^3)}{10^7} = 68.37$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S ₁
1	0.15	3.3	8.35	68.37	570.8	7654	1.07
2	0.15	4.3	31.99	"	2187	"	1.29
3	0.15	6.61	106.1	"	7252	"	1.94
4	0.15	16.51	346.5	"	23690	"	4.10
5	0.15	11.0	248.12	"	16964	"	3.22

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 10 of 57

Subject ADDED RESISTANCE FOR SEA STATE - ATE 14R

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RCS Date 2/3/76 Checked _____ Reviewed _____

CALCULATION #1 FROUDE No. = 0.15 (7.54 KT.)
SEA STATE = 0.015 $H^{1/3} = 3.30$ FT.
 $F^+ = 0.20$ $F^- = 0.15$
 $S^+ = 0.020$ $S^- = 0.015$

CALCULATION #2 FROUDE No. = 0.15
SEA STATE = 0.020 $H^{1/3} = 4.40$ FT.
 $F^+ = 0.20$ $F^- = 0.15$
 $S^+ = 0.030$ $S^- = 0.020$

CALCULATION #3 FROUDE No. = 0.15
SEA STATE = 0.03 $H^{1/3} = 6.61$ FT.
 $F^+ = 0.20$ $F^- = 0.15$
 $S^+ = 0.04$ $S^- = 0.03$

CALCULATION #4 FROUDE No. = 0.15
SEA STATE = 0.075 $H^{1/3} = 16.51$ FT.
 $F^+ = 0.20$ $F^- = 0.15$
 $S^+ = 0.10$ $S^- = 0.075$

CALCULATION #5 FROUDE No. = 0.15
SEA STATE = 0.05 $H^{1/3} = 11.0$ FT.
 $F^+ = 0.20$ $F^- = 0.15$
 $S^+ = 0.075$ $S^- = 0.050$

DESIGN CALCULATION SHEET

CALCULATION #1

Sheet 11 of 12

Subject ADDED RESISTANCE FOR SEA STATE - ATF 148

Ship or Project TOWING RESISTANCE

Section

Prepared by RCS

Date 2/3/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-B/T} = 0.85$	$\frac{L/B - L/B^*}{L/B^* - L/B} = -0.5$	$\frac{CB - CB^*}{CB^* - CB} = -1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRONTS No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	5	5				
2	3		5			
3	23	23				
4	17			8.4		
5	9	9				
6	7		9			
7	32	32			8.35	
8	31					
9	6	6				
10	5		6			
11	25	25				
12	25			8.55		
13	9	9				
14	8		9			
15	27	27				8.35
16	29					
17	5	5				
18	3		5			
19	23	23				
20	16			8.4		
21	9	9				
22	7		9			
23	32	32				
24	31					
25	6	6			8.35	
26	4		6			
27	25	25				
28	24					
29	9	9		8.55		
30	8		9			
31	27	27				
32	29					

DESIGN CALCULATION SHEET

CALCULATION # 2

Sheet 12 of 57

Subject ADDED RESISTANCE FOR SEA STATE - ATF 148Ship or Project TOWING RESISTANCE

Section

Prepared by R.C.SDate 2/3/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-(B/T)^*} = 0.85$	$\frac{4/B - 4/B^*}{4/B^* - 4/B^*} = -0.23$	$\frac{CB - CB^*}{CB^* - CB^*} = -1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRONTS No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	23	23				
2	17		23			
3	59	59				
4	56			30.65		
5	32	32				
6	31		32			
7	65	65			31.99	
8	70					
9	25	25				
10	25		25			
11	54	54				
12	58			26.7		
13	27	27				
14	29		27			
15	51	51				
16	57					31.99
17	23	23				
18	16		23			
19	60	60				
20	56			30.65		
21	32	32				
22	31		32			
23	66	66				
24	70				31.99	
25	25	25				
26	24		25			
27	54	54				
28	58					
29	27	27		26.7		
30	29					
31	52		27			
32	57	52				

DESIGN CALCULATION SHEET

CALCULATION #3

Sheet 13 of 5

Subject ADDED RESISTANCE FOR SEA STATE - ATF 148Ship or Project TOWING RESISTANCE

Section

Prepared by RCSDate 2/3/76 Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T) - (B/T)^*}{(B/T)^* - (B/T)^*} = 0.85$	$\frac{L/B - L/B^*}{L/B^* - L/B^*} = -0.34$	$\frac{CB - CB^*}{CB^* - CB^*} = -1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRONDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	105	105				
2	107		105			
3	203	203				
4	229			103.3		
5	103	103				
6	116		103			
7	175	175				
8	202				111.97	
9	88	88				
10	99		88			
11	147	147				
12	174			77.8		
13	76	76				
14	88		76			
15	120	120				
16	141					106.1
17	107	107				
18	108		107			
19	208	208				
20	234			106.15		
21	106	106				
22	117		106			
23	181	181				
24	208					
25	88	88			115.21	
26	99		88			
27	149	149				
28	176					
29	78	78		79.5		
30	89		78			
31	126	126				
32	146					

DESIGN CALCULATION SHEET

CALCULATION #4

Sheet 14 of 5

Subject ADDED RESISTANCE FOR SEA STATE - ATF 148Ship or Project TOWING RESISTANCE

Section

Prepared by ICCSDate 2/3/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T) - (B/T)^-}{(B/T)^+ - (B/T)^-} = 0.85$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = -0.34$	$\frac{CB \cdot CB^-}{CB^+ \cdot CB^-} = -1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRONTS No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	412	412				
2	509					
3	496	496	412			
4	632			344		
5	332	332				
6	416		332			
7	405	405			384.38	
8	528					
9	272	272				
10	344		272			
11	322	322		225.25		
12	421					
13	217	217				
14	275		217			
15	262	262				
16	346					346.5
17	427	427				
18	528		427			
19	516	516		363.25		
20	660					
21	352	352				
22	441		352			
23	434	434				
24	568				405.19	
25	279	279				
26	355		279			
27	334	334				
28	439			237.9		
29	233	233				
30	294		233			
31	285	285				
32	377					

DESIGN CALCULATION SHEET

CALCULATION # 5

no. 2711
Sheet 15 of 5

Subject ADDED RESISTANCE FOR SEA STATE - ATF 148

Ship or Project TOWING RESISTANCE

Section

Prepared by RLS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-}=0.85$	$\frac{Y/B-Y/B^-}{Y/B^+-Y/B^-}=-0.34$	$\frac{CB-CB^-}{CB^+-CB^-}=-1.82$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRUITE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED Y/B	FOR DESIRED CB
1	278	278				
2	321		278			
3	412	412				
4	509			240.6		
5	234	234				
6	277		234			
7	332	332			267.04	
8	416					
9	196	196				
10	237		196			
11	272	272				
12	344			162.85		
13	157	157				
14	190		157			
15	217	217				
16	275					248.12
17	287	287				
18	331		287			
19	427	427				
20	528			250.45		
21	244	244				
22	288		244			
23	352	352				
24	441					
25	200	200			277.43	
26	242		200			
27	279	279				
28	355					
29	166	166		171.1		
30	198		166			
31	233	233				
32	294					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 16 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CGN-25

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RLS Date 2/4/76 Checked _____ Reviewed _____

CALCULATIONS FOR SHIP - CGN-25

$$\begin{aligned} LBP/LWL &= 0.983 \quad (\text{ASSUMED}) \\ L = LBP &= 0.983 (540) = 530.82 \end{aligned}$$

$$\text{FROUDE No. FOR 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times (540)}} = 0.153$$

$$\text{USE FROUDE No.} = 0.10 \equiv 7.8 \text{ KT.}$$

$$B/T = 3.0, \quad 4/B = 9.53, \quad CB = 0.472$$

$$\begin{aligned} B/T^+ &= 4.0 & B/T^- &= 3.0 \\ 4/B^+ &= 8.5 & 4/B^- &= 7.0 \\ CB^+ &= 0.60 & CB^- &= 0.55 \end{aligned}$$

$$\text{CALM WATER RESISTANCE AT 7.8 KT.} = 22386$$

$$\text{MULTIPLIER} = \frac{99 (LBP)^3}{10^7} = 957.87$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.10	7.96	7.31	957.87	7002	22386	1.31
2	0.10	10.62	14.99	"	14358	"	1.64
3	0.10	15.92	28.03	"	26849	"	2.20
4	0.10	39.81	62.88	"	60231	"	3.69

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 17 of 57

Subject ADDED RESISTANCE FOR SEA STATE CGN-25

Ship or Project TOWING RESISTANCE

Section _____ Prepared by BCS Date _____ Checked _____ Reviewed _____

CALCULATION #1 FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.015 $H^{1/3} = 7.96$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.020 \quad S^- = 0.015$$

CALCULATION #2 FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.020 $H^{1/3} = 10.62$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.025 \quad S^- = 0.020$$

CALCULATION #3 FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.030 $H^{1/3} = 15.92$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.040 \quad S^- = 0.030$$

CALCULATION #4 FROUDE No. = 0.10 (7.8 KT.)
SEA STATE = 0.075 $H^{1/3} = 39.81$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.100 \quad S^- = 0.075$$

CALCULATION #5 FROUDE No. = _____ (_____ KT.)
SEA STATE = _____ $H^{1/3} =$ _____ FT.

$$F^+ = \quad F^- =$$
$$S^+ = \quad S^- =$$

Subject ADDED RESISTANCE FOR SEA STATE - CGN-25

Ship or Project TOWING RESISTANCE

Section

Prepared by RGS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B^*/T)}{B^*/T - B^*/T} = 1$	$\frac{4/B - 4/B^*}{4/B^* - 4/B^*} = 1.69$	$\frac{CB - CB^*}{CB^* - CB^*} = -1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	8	8				
2	6		8			
3	26	26				
4	25			10		
5	10	10				
6	9		10			
7	25	25			7.31	
8	27					
9	7	7				
10	7		7			
11	21	21				
12	23			9		
13	9	9				
14	8		9			
15	20	20				
16	22					7.31
17	8	8				
18	6		8			
19	26	26				
20	25			10		
21	10	10				
22	9		10			
23	26	26				
24	27					
25	7	7			7.31	
26	6		7			
27	21	21				
28	22					
29	9	9		9		
30	9		9			
31	21	21				
32						

DESIGN CALCULATION SHEET

CALCULATION #2

no. 2711
Sheet 17 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CGN-25

Ship or Project TOWING RESISTANCE

Section

Prepared by RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0$	$\frac{4B-4B^-}{4B^+-4B^-} = 1.69$	$\frac{CB-CB^-}{CB^+-CB^-} = -1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	25	25				
2	27		25			
3	44	44				
4	51			25		
5	27	27				
6	28		27			
7	44	44				
8	49				16.55	
9	20	20				
10	22		20			
11	33	33				
12	38			20		
13	21	21				
14	23		21			
15	34	34				
16	38					14.99
17	26	26				
18	27		26			
19	46	46				
20	52			26		
21	29	29				
22	29		29			
23	49	49				
24	52				17.55	
25	21	21				
26	23		21			
27	36	36				
28	40					
29	24	24		21		
30	24		24			
31	38	38				
32	41					

M. Rosenblatt & Son, Inc.

No. 3419

DESIGN CALCULATION SHEET

CALCULATION #3

Sheet 22 of 27

Subject ADDED RESISTANCE FOR SEA STATE - 63Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F'}{F-F'} = 0$	$\frac{S-S'}{S-S'} = 0$	$\frac{(B/T)-(B'/T)}{B/T - B'/T} = 0$	$\frac{4B-4B'}{4B-4B'} = 1.69$	$\frac{CB-CB'}{CB-CB'} = -1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	63	63				
2	76		63			
3	99	99				
4	120			63		
5	63	63				
6	71		63			
7	96	96			34.27	
8	112					
9	46	46				
10	55		46			
11	69	69				
12	86			46		
13	47	47				
14	53		47			
15	70	70				
16	82					28.03
17	67	67				
18	78		67			
19	106	106				
20	126			67		
21	69	69				
22	76		69			
23	107	107				
24	122				38.27	
25	50	50				
26	58		50			
27	77	77				
28	92			50		
29	53	53				
30	58		53			
31	80	80				
32	97					

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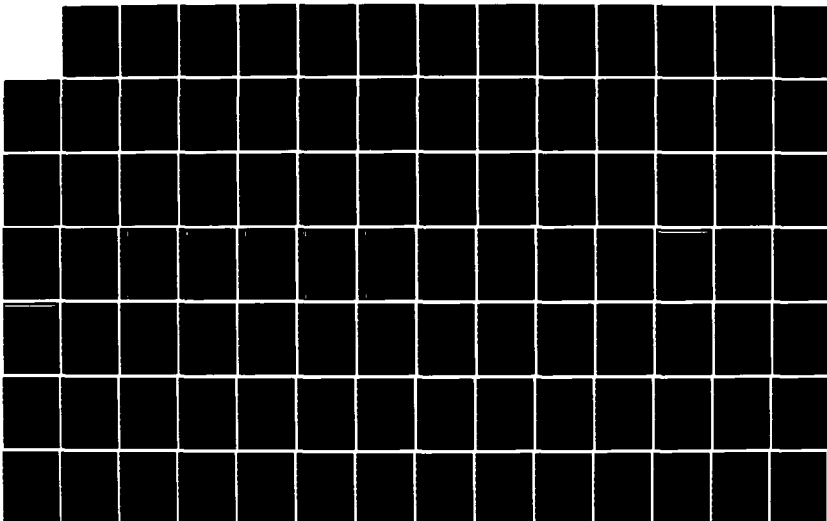
DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE
DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U)
ROSENBLATT (M) AND SON INC NEW YORK APR 76
N00024-74-C-5508

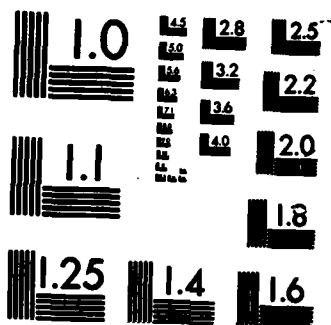
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DESIGN CALCULATION SHEET

CALCULATION #4

No. 3417

Sheet 21 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CGN-25Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-B/T} = 0$	$\frac{4/B - 4/B^*}{4/B^* - 4/B} = 1.69$	$\frac{CB - CB^*}{CB^* - CB} = -1.56$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED $4/B$	FOR DESIRED CB
1	158	158				
2	217		158			
3	178	178				
4	262			158		
5	153	153				
6	203		153			
7	172	172				
8	250				75.19	
9	109	109				
10	150		109			
11	122	122				
12	182			109		
13	145	145				
14	183		145			
15	178	178				
16	236					62.88
17	172	172				
18	233		172			
19	194	194				
20	285			172		
21	173	173				
22	228		173			
23	195	195				
24	283				87.5	
25	122	122				
26	165		122			
27	137	137				
28	203			122		
29	125	125				
30	167		125			
31	139	139				
32	206					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 22 of 57

Subject ADDED RESISTANCE FOR SEA STATE - FF 1040

Ship or Project TOWING RESISTANCE

Section

Prepared by RCS

Date 11/23/75 Checked

Reviewed

CALCULATIONS FOR SHIP FF 1040

$$LBP/LWL = 0.983 \text{ (ASSUMED)}$$

$$L = LBP = 0.983 (390) = 383.37$$

$$\text{FROUDE No. FOR 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times 390}} = 0.18 \text{ USE FROUDE No. } = 0.15$$

$$B/T = 3.157, \quad L/B = 8.67, \quad CB = 0.454$$

$$B/T^+ = 4.0$$

$$B/T^- = 3.0$$

$$L/B^+ = 8.5$$

$$L/B^- = 7.0$$

$$CB^+ = 0.60$$

$$CB^- = 0.55$$

$$\text{FROUDE No.} = 0.15 \quad \text{SPEED} = 9.94 \text{ KT.}$$

$$\text{CALM WATER RESISTANCE AT 10 KT.} = 22820$$

$$\text{MULTIPLIER} = \frac{9.9 (LBP)^3}{10^7} = 360.8$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.15	5.75	7.0	360.8	2526	22820	1.11
2	0.15	11.5	47.11	"	16997	"	1.74
3	0.15	28.75	104.8	"	37801	"	2.66
4	0.15	9.58	31.8	"	11427	"	1.5

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 23 of 57

Subject ADDED RESISTANCE - SEA STATE - FF1040

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RCS Date 12/10/75 Checked _____ Reviewed _____

CALCULATION #1 FROUDE # = 0.15 (9.94 KT.)
SEA STATE = 0.015 H_{1/3} = 5.75

$$F^+ = 0.20 \quad F^- = 0.15$$
$$S^+ = 0.020 \quad S^- = 0.015$$

CALCULATION #2 FROUDE # = 0.15
SEA STATE = 0.30 (11.5 FT.)

$$F^+ = 0.20 \quad F^- = 0.15$$
$$S^+ = 0.040 \quad S^- = 0.030$$

CALCULATION #3 FROUDE # = 0.15
SEA STATE = 0.075 (28.75 FT.)

$$F^+ = 0.20 \quad F^- = 0.15$$
$$S^+ = 0.100 \quad S^- = 0.075$$

CALCULATION #4 FROUDE # = 0.15
SEA STATE = 0.025 (9.58 FT.)

$$F^+ = 0.20 \quad F^- = 0.15$$
$$S^+ = 0.030 \quad S^- = 0.025$$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #1

No. 3419

Sheet 24 of 57

Subject ADDED RESISTANCE FOR SEA STATE - FF 1040

Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

12/10/75

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.157$	$\frac{4/B - 4/B^-}{4/B^+ - 4/B^-} = 1.213$	$\frac{CB - CB^-}{CB^+ - CB^-} = -1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	9	9				
2	8		9			
3	27	27				
4	29			9.3		
5	11	11				
6	10		11			
7	29	28			8.1	
8	29					
9	8	8				
10	8		8			
11	22	22				
12	24			8.3		
13	10	10				
14	9		10			
15	23	23				
16	24					7.0
17	9	9				
18	8		9			
19	27	27				
20	29			9.5		
21	12	12				
22	10		12			
23	29	29				
24	30				9.3	
25	9	9				
26	8		9			
27	23	23				
28	24			9.3		
29	11	11				
30	10					
31	24		11			
32	24	24				

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION # 2

No. 3419

Sheet 25 of 57

Subject ADDED RESISTANCE - SEA STATE - FF 1040

Ship or Project TOWING RESISTANCE

Section

Prepared by RGS

Date 2/2/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T} = 0.157$	$\frac{4/B - 4/B^-}{4/B^+ - 4/B} = 1.213$	$\frac{CB-CB^-}{CB^+-CB} = -1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	76	76				
2	88		76			
3	120	120				
4	141			75.22		
5	71	71				
6	79		71			
7	112	112				
8	128				50.32	
9	55	55				
10	64		55			
11	86	86				
12	102			54.69		
13	53	53				
14	60		53			
15	82	82				
16	94					47.11
17	78	78				
18	89		78			
19	126	126				
20	146			77.69		
21	76	76				
22	83		76			
23	122	122				
24	137				53.81	
25	58	58				
26	66		58			
27	92	92				
28	107					
29	58	58		58		
30	64					
31	92		58			

Subject ADDED RESISTANCE - SEA STATE - FF 1040

 Ship or Project TOWING RESISTANCE

Section

 Prepared by RCS

 Date 2/2/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{B/T^*-B/T^*} = 0.157$	$\frac{4/B - 4/B^*}{4/B^* - 4/B^*} = 1.213$	$\frac{CB - CB^*}{CB^* - CB^*} = -1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED $4/B$	FOR DESIRED CB
1	253	253				
2	275		253			
3	269	269				
4	294			253.79		
5	258	258				
6	281		258			
7	275	275			126.95	
8	299					
9	150	150				
10	192		150			
11	182	182				
12	242			149.22		
13	145	145				
14	183		145			
15	178	178				104.8
16	236					
17	233	233				
18	294		233			
19	285	285		232.22		
20	377					
21	228	228				
22	283		228			
23	283	283				
24	372				151.06	
25	165	165				
26	208		165			
27	203	203				
28	268			165.31		
29	167	167				
30	208		167			
31	206	206				
32	172					

M. ROSENBLATT & SON, INC.

DESIGN CALCULATION SHEET

CALCULATION #4

No. 3419

Sheet 27 of 57

Subject ADDED RESISTANCE - SEA STATE - FF1040

Ship or Project TOWING RESISTANCE

Section

Prepared by PCS

Date 2/2/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T} = 0.157$	$\frac{L/B-L/B^-}{L/B^+-L/B} = 1.213$	$\frac{CB \cdot CB^-}{CB^+-CB} = -1.92$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	51	51				
2	57		51			
3	76	76				
4	88			50.69		
5	49	49				
6	53		49			
7	71	71			34.53	
8	79					
9	38	38				
10	44		38			
11	55	55				
12	64			37.37		
13	34	34				
14	38		34			
15	47	47				31.67
16	53					
17	52	52				
18	57		52			
19	78	78				
20	89			52		
21	52	52				
22	55		52			
23	76	76				
24	83				37.64	
25	40	40				
26	45		40			
27	58	58				
28	66			40.16		
29	41	41				
30	44					
31	58	58				
32	44		41			

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 25 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOR-1

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RCS Date 2/4/76 Checked _____ Reviewed _____

CALCULATIONS FOR SHIP - AOR-1

$$LBP/LWL = 0.983 \quad (\text{ASSUMED})$$

$$L = LBP = 0.983 (640) = 629.12$$

$$\text{Froude No. for 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times (640)}} = 0.14$$

$$\text{USE Froude No.} = 0.10 \equiv 8.5 \text{ KT.}$$

$$B/T = 2.95, \quad L/B = 6.67, \quad CB = 0.64$$

$$\begin{array}{ll} B/T^+ = 3.0 & B/T^- = 2.0 \\ L/B^+ = 7.0 & L/B^- = 5.5 \\ CB^+ = 0.65 & CB^- = 0.60 \end{array}$$

$$\text{CALM WATER RESISTANCE AT 8.5 KT.} = 48077$$

$$\text{MULTIPLIER} = \frac{99 (LBP)^3}{10^7} = 1594.7$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.10	9.44	10.06	1594.7	16043	48077	1.33
2	0.10	12.58	27.26	"	43472	"	1.90
3	0.10	18.87	74.39	"	118633	"	3.47
4	0.10	31.46	154.16	"	245833	"	6.11
						"	

Subject ADDED RESISTANCE FOR SEA STATE - AOR-1Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

2/4/76

Checked

Reviewed

CALCULATION #1

FROUDE No. = 0.10

(8.5 KT.)

SEA STATE = 0.015

 $H^{1/3} = 9.44$ FT.

$F^+ = 0.15$

$F^- = 0.10$

$S^+ = 0.020$

$S^- = 0.015$

CALCULATION #2

FROUDE No. = 0.10

(8.5 KT.)

SEA STATE = 0.020

 $H^{1/3} = 12.58$ FT.

$F^+ = 0.20$

$F^- = 0.10$

$S^+ = 0.025$

$S^- = 0.02$

CALCULATION #3

FROUDE No. = 0.10

(8.5 KT.)

SEA STATE = 0.030

 $H^{1/3} = 18.87$ FT.

$F^+ = 0.20$

$F^- = 0.10$

$S^+ = 0.040$

$S^- = 0.03$

CALCULATION #4

FROUDE No. = 0.10

(8.5 KT.)

SEA STATE = 0.05

 $H^{1/3} = 31.46$ FT.

$F^+ = 0.20$

$F^- = 0.10$

$S^+ = 0.075$

$S^- = 0.05$

CALCULATION #5

FROUDE No. =

(KT.)

SEA STATE =

 $H^{1/3} =$ FT.

$F^+ =$

$F^- =$

$S^+ =$

$S^- =$

DESIGN CALCULATION SHEET

CALCULATION # 1

no. 5711

Sheet 30 of 5

Subject ADDED RESISTANCE FOR SEA STATE - AOR-1Ship or Project TOWING RESISTANCE

Section

Prepared by RCSDate 2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.95$	$\frac{4/B - 4/B^-}{4/B^+ - 4/B^-} = 0.78$	$\frac{CB - CB^-}{CB^+ - CB^-} = 0.8$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRUITE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED $4/B$	FOR DESIRED CB
1	6	6				
2	5		6			
3	29	29				
4	23			10.75		
5	11	11				
6	9		11			
7	32	32			10.09	
8	32					
9	8	8				
10	6		8			
11	26	26				
12	25			9.9		
13	10	10				
14	9		10			
15	26	26				10.06
16	27					
17	6	6				
18	4		6			
19	29	29				
20	22			10.75		
21	11	11				
22	9		11			
23	32	32				
24	31					
25	7	7			10.05	
26	6		7			
27	25	25				
28	25					
29	10	10		9.85		
30	9		10			
31	26	26				
32	27					

DESIGN CALCULATION SHEET

CALCULATION #2

No. 5717
Sheet 31 of 5Subject ADDED RESISTANCE FOR SEA STATE - AOB-1Ship or Project TOWING RESISTANCE

Section

Prepared by RCSDate 2/4/76 Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T) - (B/T)^-}{(B/T)^+ - (B/T)^-} = 0.95$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 0.78$	$\frac{CB - CB^-}{CB^+ - CB^-} = 0.8$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRUITE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	29	29				
2	23		29			
3	64	64				
4	60			31.85		
5	32	32				
6	32		32			
7	62	62			27.29	
8	66					
9	26	26				
10	25		26			
11	51	51				
12	54			26		
13	26	26				
14	27		26			
15	46	46				
16	52					27.26
17	29	29				
18	22		29			
19	65	65				
20	61			31.85		
21	32	32				
22	31		32			
23	63	63				
24	66					
25	25	25			27.25	
26	25		25			
27	50	50				
28	54					
29	26	26		25.95		
30	27					
31	47	47	26			
32	52					

DESIGN CALCULATION SHEET

CALCULATION #3

Sheet 32 of 5

Subject ADDED RESISTANCE FOR SEA STATE - ADR-1Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-} = 0.95$	$\frac{4/B - 4/B^-}{4/B^+ - 4/B^-} = 0.78$	$\frac{CB-CB^-}{CB^+-CB^-} = 0.8$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROM DE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED $4/B$	FOR DESIRED CB
1	107	107				
2	107		- 107			
3	182	182				
4	208			- 95.6		
5	95	95				
6	106		- 95			
7	155	155				
8	181				- 73.68	
9	77	77				
10	88		- 77			
11	122	122				
12	149			- 67.5		
13	67	67				
14	78		- 67			
15	106	106				
16	126					- 74.39
17	109	109				
18	109		- 109			
19	187	187				
20	214			- 96.65		
21	96	96				
22	107		- 96			
23	159	159				
24	186					
25	76	76				- 74.62
26	38		- 76			
27	123	123				
28	151			- 68.4		
29	68	68				
30	79		- 68			
31	110	110				
32	129					

DESIGN CALCULATION SHEET

CALCULATION #4

No. 5717

Sheet 33 of 5

Subject ADDED RESISTANCE FOR SEA STATE - A02-1Ship or Project TOWING RESISTANCE

Section

Prepared by RCSDate 2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.95$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 0.78$	$\frac{CB - CB^-}{CB^+ - CB^-} = 0.80$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRUITE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	242	242				
2	287		242			
3	325	325				
4	427			203.05		
5	201	201				
6	244		201			
7	263	263				
8	352				150.13	
9	158	158				
10	200		158			
11	203	203				
12	279			135.2		
13	134	134				
14	166		134			
15	172	172				
16	233					154.16
17	249	249				
18	297		249			
19	336	336				
20	446			209.1		
21	207	207				
22	252		207			
23	271	271				
24	366				155.16	
25	158	158				
26	203		158			
27	205	205				
28	286			139.95		
29	139	139				
30	171		139			
31	179	179				
32	243					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 34 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOE - 1

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RLS Date 2/5/76 Checked _____ Reviewed _____

CALCULATIONS FOR SHIP - AOE-1

$$LBP/LWL = 0.983 \quad (\text{ASSUMED})$$

$$L = LBP = 0.983 (770) = 756.91$$

$$\text{FROUDE No. FOR 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times (770)}} = 0.128$$

$$\text{USE FROUDE No.} = 0.10 \approx 9.32$$

$$B/T = 2.71, \quad L/B = 7.07, \quad CB = 0.58$$

$$\begin{array}{ll} B/T^+ = 3.0 & B/T^- = 2.0 \\ L/B^+ = 8.5 & L/B^- = 7.0 \\ CB^+ = 0.60 & CB^- = 0.55 \end{array}$$

$$\text{CALM WATER RESISTANCE AT 9.32 KT.} = 86296$$

$$\text{MULTIPLIER} = \frac{99 (LBP)^3}{10^7} = 2777.1$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.10	11.35	9.37	2777.1	26021	86296	1.30
2	0.10	15.13	25.47	"	70722	"	1.82
3	0.10	22.7	67.82	"	188348	"	3.18
4	0.10	37.85	135.67	"	376780	"	5.37

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 35 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOE-1

Ship or Project TOWING RESISTANCE

Section _____ Prepared by ECS Date 2/5/76 Checked _____ Reviewed _____

CALCULATION #1 FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.015 $H \frac{1}{3} = 11.35$ FT.

$$\begin{array}{ll} F^+ = 0.15 & F^- = 0.10 \\ S^+ = 0.020 & S^- = 0.015 \end{array}$$

CALCULATION #2 FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.020 $H \frac{1}{3} = 15.13$ FT.

$$\begin{array}{ll} F^+ = 0.15 & F^- = 0.10 \\ S^+ = & S^- = \end{array}$$

CALCULATION #3 FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.03 $H \frac{1}{3} = 22.7$ FT.

$$\begin{array}{ll} F^+ = 0.15 & F^- = 0.10 \\ S^+ = 0.040 & S^- = 0.030 \end{array}$$

CALCULATION #4 FROUDE No. = 0.10 (9.32 KT.)
SEA STATE = 0.05 $H \frac{1}{3} = 37.85$ FT.

$$\begin{array}{ll} F^+ = 0.15 & F^- = 0.10 \\ S^+ = 0.075 & S^- = 0.05 \end{array}$$

CALCULATION #5 FROUDE No. = (KT.)
SEA STATE = $H \frac{1}{3} =$ FT.

$$\begin{array}{ll} F^+ = & F^- = \\ S^+ = & S^- = \end{array}$$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #1

No. 3419

Sheet 36 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOE-1Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

2/5/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-(B/T)^*} = 0.71$	$\frac{4/B-4/B^*}{4/B^*-4/B^*} = 0.05$	$\frac{CB-CB^*}{CB^*-CB^*} = 0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	8	8				
2	6					
3	26	26	8			
4	25			9.42		
5	10	10				
6	9		10			
7	25	25			9.37	
8	27					
9	7	7				
10	7		7			
11	21	21				
12	23			8.42		
13	9	9				
14	8		9			9.37
15	20	20				
16	22					
17	8	8				
18	6		8			
19	26	26				
20	25			9.42		
21	10	10				
22	9		10			
23	26	26				
24	27				9.37	
25	7	7				
26	6		7			
27	21	21				
28	22			8.42		
29	9	9				
30	9		9			
31	21	21				
32	23					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #2

No. 3417

Sheet 37 of 57

Subject HIDDEN RESISTANCE FOR SEA STATE - AOE - 1Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/5/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/A)-(B/T)}{B/T - B/A} = 0.71$	$\frac{4/B - 4/B^*}{4/B^* - 4/B} = 0.05$	$\frac{CB - CB^*}{CB^* - CB} = 0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	26	26				
2	25		- 26			
3	51	51				
4	54			- 25.29		
5	25	25				
6	27		- 25			
7	44	44			- 25.04	
8	51					
9	21	21				
10	23		- 21			
11	37	37		- 20.29		
12	45					
13	20	20				
14	22		- 20			- 25.47
15	33	33				
16	38					
17	26	26				
18	25		- 26			
19	51	51		- 26		
20	54					
21	26	26				
22	27		- 26			
23	46	46				
24	52				- 25.75	
25	21	21				
26	22		- 21			
27	38	38				
28	44			- 21		
29	21	21				
30	23		- 21			
31	36	36				
32	40					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #3

No. 3419

Sheet 38 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOE-1Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

2/5/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T}=0.71$	$\frac{Y_B-Y_B^-}{Y_B^+-Y_B^-}=0.05$	$\frac{CB-CB^-}{CB^+-CB^-}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED Y_B	FOR DESIRED CB
1	77	77				
2	88		77			
3	120	120				
4	147			67.06		
5	63	63				
6	76		63			
7	99	99			66.11	
8	120					
9	53	53				
10	67		53			
11	83	83				
12	107			48.03		
13	46	46				
14	55		46			67.82
15	69	69				
16	86					
17	77	77				
18	88		77			
19	122	122				
20	149			69.9		
21	67	67				
22	78		67			
23	106	106				
24	126				68.96	
25	54	54				
26	68		54			
27	85	85				
28	108			51.16		
29	50	50				
30	58		50			
31	77	77				
32	00					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #3

No. 3419

Sheet 3A of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOE-1Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

2/5/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-}=0$	$\frac{S-S^-}{S^+-S^-}=0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T}=0.71$	$\frac{4/B-4/B^-}{4/B^+-4/B}=0.05$	$\frac{CB-CB^-}{CB^+-CB}=0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	77	77				
2	88		77			
3	120	120				
4	147			67.06		
5	63	63				
6	76		63			
7	99	99			66.11	
8	120					
9	53	53				
10	67		53			
11	83	83				
12	107			48.03		
13	46	46				
14	55		46			67.82
15	69	69				
16	86					
17	77	77				
18	88		77			
19	122	122				
20	149			69.9		
21	67	67				
22	78		67			
23	106	106				
24	126				68.96	
25	54	54				
26	68		54			
27	85	85				
28	108			51.16		
29	50	50				
30	58		50			
31	77	77				
32	92					

DESIGN CALCULATION SHEET

CALCULATION #4

No. 3417

Sheet 29 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AOE-1

Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/5/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.71$	$\frac{4B-4B^-}{4B^+-4B^-} = 0.05$	$\frac{CB-CB^-}{CB^+-CB^-} = 0.60$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	155	155				
2	196		155			
3	199	199				
4	272			132.99		
5	124	124				
6	157		124			
7	158	158				
8	217				130.89	
9	103	103				
10	138		103			
11	129	129				
12	186			90.93		
13	86	86				
14	110		86			
15	109	109				135.67
16	150					
17	158	158				
18	200		158			
19	203	203				
20	279			140.96		
21	134	134				
22	166		134			
23	172	172				
24	233				138.86	
25	106	106				
26	141		106			
27	135	135				
28	193			98.9		
29	96	96				
30	119		96			
31	122	122				
32	165					

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 40 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CA 139

Ship or Project TOWING RESISTANCE

Section

Prepared by RCS

Date 11/7/75 Checked

Reviewed

CALCULATIONS FOR SHIP CA 139

FOR ALL CALCULATIONS THE FOLLOWING RELATIONSHIPS APPLY:

$$LBP/LWL = 0.983 \text{ (ASSUMED)}$$

$$L = LBP = 0.983 (700) = 688.1$$

$$\text{FROUDE No. FOR 12 KT.} = \frac{12.0 \times 1.689}{\sqrt{32.174 \times 700}} = 0.135 \text{ USE FR No.} = 0.1$$

$$B/T = 2.945, \quad L/B = 9.126, \quad CB = 0.593$$

$$B/T^+ = 3.0$$

$$B/T^- = 2.0$$

$$L/B^+ = 8.5$$

$$L/B^- = 7.0$$

$$CB^+ = 0.60$$

$$CB^- = 0.55$$

STILL WATER RESISTANCE AT 8.89 KT. = 37082 LB.

$$\text{MULTIPLIER} = \frac{99 (LBP)^3}{10^7} = 2087$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S ₁
1	0.10	10.32	8.473	2087	17683	37082	1.48
2	0.10	20.64	38.6	"	80558	"	3.17
3	0.10	40	75.18	"	156909	"	5.23
4	0.10	27.52	55.97	"	116812	"	4.15

DESIGN CALCULATION SHEET

Sheet 41 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CA 139

Ship or Project TOWING RESISTANCE

Section

Prepared by RCS

Date 11/7/75 Checked

Reviewed

CALCULATION #1 FROUDE # = 0.1 (8.89 KT.)
SEA STATE $S = 0.015$ $H^{1/3} = 10.32$

$$F^+ = 0.15$$

$$F^- = 0.1$$

$$S^+ = 0.020$$

$$S^- = 0.015$$

CALCULATION #2 FROUDE # = 0.10
SEA STATE = 0.030 $H^{1/3} = 20.64$

$$F^+ = 0.15$$

$$F^- = 0.10$$

$$S^+ = 0.030$$

$$S^- = 0.025$$

CALCULATION #3 FROUDE # = 0.10
SEA STATE = 0.058 $H^{1/3} = 40'$

$$F^+ = 0.15$$

$$F^- = 0.1$$

$$S^+ = 0.075$$

$$S^- = 0.050$$

CALCULATE #4 FROUDE # = 0.10
SEA STATE = 0.04 $H^{1/3} = 27.52$

$$F^+ = 0.15$$

$$F^- = 0.1$$

$$S^+ = 0.05$$

$$S^- = 0.04$$

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #1

No. 3419

Sheet 42 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CA 139Ship or Project EMER. TOWING GEAR

Section

Prepared by

RCS

Date 11/7/75

Checked

Reviewed

#1		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.945$	$\frac{4/B - 4/B^-}{4/B^+ - 4/B^-} = 1.417$	$\frac{CB - CB^-}{CB^+ - CB^-} = -0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	8	- 8				
2	6					
3	26	- 26	- 8			
4	25					
5	10	- 10		9.89		
6	9		10			
7	25	- 25				
8	27				8.473	
9	7	- 7				
10	7		7			
11	21	- 21				
12	23			8.89		
13	9	- 9				
14	8		9			8.473
15	20	- 20				
16	22					
17	8	- 8				
18	6		8			
19	21	- 26				
20	25			9.89		
21	10	- 10				
22	9		10			
23	21	- 26				
24	27				8.473	
25	7	- 7				
26	6		7			
27	21	- 21				
28	22			8.89		
29	9	- 9				
30	9		9			
31	21	- 21				
32	22					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #2

No. 3419

Sheet 43 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CA 137

Ship or Project EMER. TOWING GEAR

Section

Prepared by RCS

Date 11/7/75

Checked

Reviewed

#2		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 1$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T} = 0.245$	$\frac{L/B-L/B^-}{L/B^+-L/B} = 1.417$	$\frac{CB-CB^-}{CB^+-CB} = -0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	51	51				
2	54					
3	77	77	77			
4	88					
5	44	44		63.77		
6	51		63			
7	63	63				
8	76				39.14	
9	37	37				
10	45		53			
11	53	53				
12	67			46.39		
13	33	33				
14	38		46			
15	46	46				38.6
16	55					
17	51	51				
18	54		77			
19	77	77				
20	88			67.55		
21	46	46				
22	52		67			
23	67	67				
24	78				42.99	
25	38	38				
26	44		54			
27	54	54				
28	68			50.22		
29	36	36				
30	40		50			
31	50	50				
32	50					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #2

No. 3419

Sheet 44 of 57

Subject ADDED RESISTANCE FOR SEA STATE - CA 139Ship or Project EMERG. TOWING GEAR

Section

Prepared by

RCS

Date 11/7/75

Checked

Reviewed

#3		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0.32$	$\frac{(B/T)-(B/T)^-}{B/T^+-B/T^-} = 0.945$	$\frac{4/B-4/B^-}{4/B^+-4/B^-} = 1.417$	$\frac{CB-CB^-}{CB^+-CB^-} = -0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED $4/B$	FOR DESIRED CB
1	155	155				
2	196		169.1			
3	199	199				
4	272			136.76		
5	124	124				
6	157		134.88			
7	158	158				
8	217				76.65	
9	103	103				
10	138		111.3			
11	129	129				
12	126			94.34		
13	86	86				
14	110		93.36			
15	109	109				75.18
16	150					
17	158	158				
18	200		172.4			
19	203	203				
20	279			147.6		
21	134	134				
22	166		146.16			
23	172	172				
24	233				87.12	
25	106	106				
26	141		115.28			
27	135	135				
28	193			104.92		
29	96	96				
30	119					
31	122	122	104.32			

Subject ADDED RESISTANCE FOR SEA STATE - CA 139

 Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date

2/3/76

Checked

Reviewed

#4		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T) - (B/T)^-}{B/T^+ - B/T^-} = 0.945$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 1.417$	$\frac{CB \cdot CB^-}{CB^+ \cdot CB^-} = -0.14$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	120	120				
2	147		120			
3	155	155				
4	196			100.16		
5	99	99				
6	120		99			
7	124	124			57.1	
8	157					
9	83	83				
10	107		83			
11	103	103				
12	138			69.77		
13	69	69				
14	86		69			
15	86	86				55.97
16	110					
17	122	122				
18	149		122			
19	158	158				
20	200			106.88		
21	106	106				
22	126		106			
23	134	134				
24	166				65.2	
25	85	85				
26	108		85			
27	106	106				
28	141			77.44		
29	77	77				
30	92					
31	96	96				
32	119		77			

No. 3417
Sheet 46 of 57

Section

Prepared by RCS

Date 2/4/76 Checked _____

Reviewed

$$\begin{aligned} LBP/LWL &= 0.983 \quad (\text{ASSUMED}) \\ L = LBP &= 0.983 (483.5) = 475.28 \end{aligned}$$

$$\text{Froude No. FOR 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times (493.5)}} = 0.16$$

USE FROUDE No. = 0.10 \equiv 7.38 KT.

$$B/T = 3.65, \quad Y_B = 6.60, \quad CB = 0.56$$

$$\begin{array}{ll} B/T^+ = 4.0 & B/T^- = 3.0 \\ Y_B^+ = 7.0 & Y_B^- = 5.5 \\ CB^+ = 0.60 & CB^- = 0.55 \end{array}$$

CALM WATER RESISTANCE AT 7.38 KT. = 19,470

$$\text{MULTIPLIER} = \frac{99 \text{ (LBP)}^3}{10^7} = 687.6$$

CALC. No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.10	7.13	11.7	687.6	8045	19470	1.41
2	0.10	9.51	28.84	"	19832	"	2.02
3	0.10	14.26	71.06	"	48861	"	3.51
4	0.10	35.65	180.61	"	124187	"	7.38

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #1

No. 3417

Sheet 47 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AF 58Ship or Project TOWING RESISTANCE

Section

Prepared by RCSDate 2/4/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-(B/T)^*} = 0.65$	$\frac{Y_B - Y_B^*}{Y_B^* - Y_B^*} = 1.73$	$\frac{CB - CB^*}{CB^* - CB^*} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED Y_B	FOR DESIRED CB
1	11	11				
2	9		11			
3	32	32				
4	32			12.3		
5	13	13				
6	12		13			
7	34	34			11.57	
8	34					
9	10	10				
10	9		10			
11	25	25				
12	27			11.3		
13	12	12				
14	11		12			
15	27	27				
16	28					11.7
17	11	11				
18	9		11			
19	32	32				
20	32			12.95		
21	14	14				
22	12		14			
23	35	35				
24	35					
25	10	10			12.22	
26	9		10			
27	26	26				
28	27			11.95		
29	13	13				
30	12		13			
31	29	29				
32	29					

M. ROSENBLATT & SON, INC.

DESIGN CALCULATION SHEET

CALCULATION # 2

No. 3417

Sheet 48 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AF 5BShip or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.65$	$\frac{4B-4B^-}{4B^+-4B^-} = 0.73$	$\frac{CB-CB^-}{CB^+-CB^-} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/B	FOR DESIRED CB
1	32	32				
2	32		32			
3	61	61				
4	65			33.3		
5	34	34				
6	34		34			
7	60	60				
8	65				28.66	
9	25	25				
10	27		25			
11	44	44				
12	51			26.95		
13	27	27				
14	28		27			
15	44	44				28.84
16	49					
17	32	32				
18	32		32			
19	62	62				
20	66			33.95		
21	35	35				
22	35		35			
23	64	64				
24	67					
25	26	26			29.57	
26	27		26			
27	46	46				
28	52			27.95		
29	29	29				
30	29		29			
31	49	49				
32	52					

Subject ADDED RESISTANCE FOR SEA STATE - AF 58

 Ship or Project TOWING RESISTANCE

 Section _____ Prepared by RCS Date 2/4/76 Checked _____ Reviewed _____

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T^-} = 0.65$	$\frac{Y_B - Y_B^-}{Y_B^+ - Y_B^-} = 0.73$	$\frac{CB - CB^-}{CB^+ - CB^-} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED Y_B	FOR DESIRED CB
1	91	91				
2	103		91			
3	148	148				
4	175			89.05		
5	88	88				
6	99		88			
7	140	140			70.03	
8	161					
9	63	63				
10	76		63			
11	99	99				
12	120			63		
13	63	63				
14	71		63			
15	96	96				71.06
16	112					
17	95	95				
18	106		95			
19	155	155		94.35		
20	181					
21	94	94				
22	103		94			
23	152	152				
24	172				75.33	
25	67	67				
26	76		67			
27	106	106				
28	126			68.3		
29	69	69				
30	76		69			
31	107	107				
32	122					

M. ROSENBLATT & SON, INC.

DESIGN CALCULATION SHEET

CALCULATION #4

No. 3417

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Subject ADDED RESISTANCE FOR SEA STATE - AF 58

Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+- (B/T)^-} = 0.65$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 0.73$	$\frac{CB - CB^-}{CB^+ - CB^-} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	248	248				
2	332		248			
3	282	282				
4	405			236.95		
5	231	231				
6	305		231			
7	262	262				
8	377				176.94	
9	158	158				
10	217		158			
11	178	178				
12	262			154.75		
13	153	153				
14	203		153			
15	172	172				180.61
16	250					
17	263	263				
18	352		263			
19	300	300				
20	434			256.5		
21	253	253				
22	334		253			
23	289	289				
24	418				195.29	
25	172	172				
26	233		172			
27	194	194				
28	285			172.65		
29	173	173				
30	228		173			
31	195	195				
32	283					

DESIGN CALCULATION SHEET

Subject ADDED RESISTANCE FOR SEA STATE - LST 1179Ship or Project TANKING RESISTANCE

Section

Prepared by

RCS

Date 2/5/76

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Reviewed

CALCULATIONS FOR SHIP - LST 1179

$$LBP/LWL = 0.983 \quad (\text{ASSUMED})$$

$$L = LBP = 0.983 (508.7) = 500$$

$$\text{Froude No. FOR 12 KT.} = \frac{12.0 \times 1.6889}{\sqrt{32.174 \times (508.7)}} = 0.16$$

$$\text{USE FROUDE No.} = 0.10 \approx 7.57 \text{ KT.}$$

$$B/T = 4.32, \quad Y/B = 7.35, \quad CB = 0.56$$

$$B/T^+ = 4.0$$

$$B/T^- = 3.0$$

$$Y/B^+ = 8.5$$

$$Y/B^- = 7.0$$

$$CB^+ = 0.60$$

$$CB^- = 0.55$$

$$\text{CALM WATER RESISTANCE AT 7.57 KT.} = 15470$$

$$\text{MULTIPLIER} = \frac{9.9 (LBP)^3}{10^7} = 800.5$$

CALC No.	FR. No.	SIGNIFICANT WAVE HGT. FT.	COEFF.	COEFF. MULT.	ADDED RESIS. LB.	CALM WATER RESIS. LB.	S _i
1	0.10	7.5	12.37	800.5	9906	15470	1.64
2	0.10	10	26.71	"	21305	"	2.38
3	0.10	15	60.72	"	48605	"	4.14
4	0.10	25	114.39	"	91568	"	6.92

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 52 of 57

Subject ADDED RESISTANCE FOR SEA STATE - LST 1179

Ship or Project TOWING RESISTANCE

Section _____ Prepared by RCS Date 2/5/76 Checked _____ Reviewed _____

CALCULATION #1 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.015 $H^{1/3} = 7.5$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.020 \quad S^- = 0.015$$

CALCULATION #2 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.020 $H^{1/3} = 10$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.025 \quad S^- = 0.020$$

CALCULATION #3 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.030 $H^{1/3} = 15$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.04 \quad S^- = 0.03$$

CALCULATION #4 FROUDE No. = 0.10 (7.57 KT.)
SEA STATE = 0.05 $H^{1/3} = 25.0$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$
$$S^+ = 0.075 \quad S^- = 0.05$$

CALCULATION #5 FROUDE No. = _____ (_____ KT.)
SEA STATE = _____ $H^{1/3} =$ _____ FT.

$$F^+ = \quad F^- =$$
$$S^+ = \quad S^- =$$

DESIGN CALCULATION SHEET

CALCULATION #1

No. 5717

Sheet 53 of 57

Subject ADDED RESISTANCE FOR SEA STATE - LST 1179Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-(B/T)^*} = 1.32$	$\frac{4/B-4/B^*}{4/B^*-4/B^*} = 0.23$	$\frac{CB-CB^*}{CB^*-CB^*} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED $4/B$	FOR DESIRED CB
1	10	10				
2	9		10			
3	25	25				
4	27			12.64		
5	12	12				
6	11		12			
7	27	27			12.11	
8	28					
9	9	9				
10	8		9			
11	20	20				
12	22			10.32		
13	10	10				
14	10		10			
15	21	21				12.37
16	23					
17	10	10				
18	9		10			
19	26	26				
20	27			13.96		
21	13	13				
22	12		13			
23	29	29				
24	29				13.43	
25	9	9				
26	9		9			
27	21	21				
28	23			11.64		
29	11	11				
30	11		11			
31	24	24				
32	24					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #2

No. 3417

Sheet 54 of 5

Subject HIDDEN RESISTANCE FOR SEA STATE - LST 1179Ship or Project TOWING RESISTANCE

Section

Prepared by

RCS

Date 2/4/76

Checked

Reviewed

		$\frac{F-F^*}{F^*-F^*} = 0$	$\frac{S-S^*}{S^*-S^*} = 0$	$\frac{(B/T)-(B/T)^*}{(B/T)^*-(B/T)^*} = 1.32$	$\frac{L/B - L/B^*}{L/B^* - L/B^*} = 0.23$	$\frac{CB \cdot CB^*}{CB^* \cdot CB^*} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE No.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	25	25				
2	27		25			
3	44	44				
4	51			27.64		
5	27	27				
6	28		27			
7	44	44			26.19	
8	49					
9	20	20				
10	22		20			
11	33	33				
12	38			21.32		
13	21	21				
14	23		21			
15	34	34				
16	38					
17	26	26				26.71
18	27		26			
19	46	46				
20	52			29.96		
21	29	29				
22	29		29			
23	49	49				
24	52				28.81	
25	21	21				
26	23		21			
27	36	36				
28	40			24.96		
29	24	24				
30	24		24			
31	38	38				
32	41					

M. Rosenblatt & Son, Inc.

DESIGN CALCULATION SHEET

CALCULATION #3

No. 3419

Sheet 55 of 57

Subject ADDED RESISTANCE FOR SEA STATE - LST 1179

Ship or Project TOWING RESISTANCE

Section

Prepared by RGS

Date 2/5/76

Checked

Reviewed

		$\frac{F-F'}{F^+-F^-}=0$	$\frac{S-S'}{S^+-S^-}=0$	$\frac{(B/T)-(B'/T)}{B/T - 4/5} = 1.32$	$\frac{4/8 - 4/8'}{4/8^+ - 4/8^-} = 0.23$	$\frac{CB - CB'}{CB^+ - CB^-} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FROUDE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED 4/8	FOR DESIRED CB
1	63	63				
2	76		63			
3	99	99				
4	120			63		
5	63	63				
6	71		63			
7	96	96				
8	112				59.39	
9	46	46				
10	55		46			
11	69	69				
12	86			47.32		
13	47	47				
14	53		47			
15	70	70				60.72
16	82					
17	67	67				
18	78		67			
19	106	106				
20	126			69.64		
21	69	69				
22	76		69			
23	107	107				
24	122				66.03	
25	50	50				
26	58		50			
27	77	77				
28	92			53.96		
29	53	53				
30	58		53			
31	80	80				
32	97					

Subject ADDED RESISTANCE FOR SEA STATE - LST 1179Ship or Project TOWING RESISTANCESection _____ Prepared by RCS Date 2/5/76 Checked _____ Reviewed _____

		$\frac{F-F^-}{F^+-F^-} = 0$	$\frac{S-S^-}{S^+-S^-} = 0$	$\frac{(B/T)-(B/T)^-}{(B/T)^+-B/T} = 1.32$	$\frac{L/B - L/B^-}{L/B^+ - L/B^-} = 0.23$	$\frac{CB \cdot CB^-}{CB^+ \cdot CB^-} = 0.20$
COLUMN	1	2	3	4	5	6
LINE		FOR DESIRED FRIDGE NO.	FOR DESIRED SEA STATE	FOR DESIRED B/T	FOR DESIRED L/B	FOR DESIRED CB
1	124	124				
2	157		124			
3	158	158				
4	217			118.72		
5	120	120				
6	146		120			
7	153	153				
8	203				111.19	
9	86	86				
10	110		86			
11	109	109				
12	150			86		
13	86	86				
14	105		86			
15	108	108				
16	145					114.39
17	134	134				
18	166		134			
19	172	172				
20	233			135.32		
21	135	135				
22	160		135			
23	173	173				
24	228				127.19	
25	96	96				
26	119		96			
27	122	122				
28	165			99.96		
29	99	99				
30	118		99			
31	125	125				
32	117					

W. ROSENBLUTH & SON, INC.
DESIGN CALCULATION SHEET

No. 3419
Sheet 57 of 57

Subject ADDED RESISTANCE FOR SEA STATE - AF SB

Ship or Project TOWING RESISTANCE

Section _____ Prepared by PCS Date 2/4/76 Checked _____ Reviewed _____

CALCULATION #1 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.015 $H^{1/3} = 7.13$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$

$$S^+ = 0.020 \quad S^- = 0.015$$

CALCULATION #2 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.020 $H^{1/3} = 9.51$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$

$$S^+ = 0.025 \quad S^- = 0.02$$

CALCULATION #3 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.03 $H^{1/3} = 14.26$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$

$$S^+ = 0.04 \quad S^- = 0.03$$

CALCULATION #4 FROUDE No. = 0.10 (7.38 KT.)
SEA STATE = 0.075 $H^{1/3} = 35.65$ FT.

$$F^+ = 0.15 \quad F^- = 0.10$$

$$S^+ = 0.100 \quad S^- = 0.075$$

CALCULATION #5 FROUDE No. = _____ (_____ KT.)
SEA STATE = _____ $H^{1/3} =$ _____ FT.

$$F^+ = \quad F^- =$$

$$S^+ = \quad S^- =$$

APPENDIX D

DEVELOPMENT OF DATA TABLE FOR CHARACTERISTICS

OF NAVAL VESSELS

Appendix D

Two data tables of naval ship characteristics were developed in order to assign calm water hull resistance curves and curves for added resistance in waves to those ship classes for which calculations were not performed.

The first two sheets 1 & 2 give the curve numbers for those ships for which calculations were performed. Calculations for hull resistance were performed for 39 ships and calculations for added resistance in waves for 9 ships.

Sheets 3 through 7 give the hull form characteristics for all the naval ship classes although blanks in the table appear when data was not readily available in the literature.

Hull resistance curves were assigned principally on the basis of block coefficient, prismatic coefficient, volumetric coefficient, L/B, and ship description. Curves for added resistance in waves were assigned principally on the basis of ship length and to a lesser extent on block coefficient.

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 7419
Sheet 1 of 7

Subject

Ship or Project TOWING RESISTANCE

CALCULATIONS FOR SHIPS USED IN THIS STUDY											
SHIP CLASS	DESCRIPTION	DISPL. A LT.	LWL L	RENN B	DRAFT T	B/T	L/B	C/S	C/P	CY 10-3	CURVE FOR HULL RESISTANCE
FF 1037	ESCORT SHIP	2725	350	40.5	13.5	3	8.64	2.54	0.51	3.22	1
FF 1040	"	3131	390	44.2	14.4	3.16	8.82	0.45	0.47	1.84	2
DD 731	DESTROYER	3890	407	44.4	14.52	3.06	9.17	0.52	0.65	2.01	3
DLG 16	GUIDED MISSILE FRIGATE	6800	510	51	15	2.83	10	0.51	0.64	1.79	4
CGN-25	"	7320	540	56.66	13.89	3.0	9.53	0.47	0.53	1.70	5
CGN-19	GUIDED MISSILE CRUISER	14,090	691.3	71.0	21.5	3.30	9.74	0.47	0.58	1.49	6
CA 139	HEAVY CRUISER	20,920	700	75.4	25.6	2.95	9.29	0.54	0.60	2.13	7
MSO 422	MINE SWEEPER	880	165	34.6	10.5	3.30	4.77	0.51	0.52	6.83	8
ATE 148	FLEET OILER	2080	224	44.9	15.75	2.85	4.99	0.46	0.50	6.47	9
AGFF-1	ESCORT RESENCRM	3500	390	43.7	14.7	2.97	8.92	0.49	0.50	2.07	10
TAGS-29	SURVILL'S SHIP	4325	357	54	16	3.33	6.11	0.49	0.50	3.32	11
AF 58	STORES SHIP	11,000	483.5	72	19.72	3.65	6.72	0.56	0.57	3.41	12
AE 21	AMMUNITION SHIP	17,303	482	72	29	2.78	6.69	0.60	0.61	5.41	13
AD-14	DESTROYER TENDER	17,000	531	73	26	2.81	7.27	0.59	0.61	3.97	14
AE 26	AMMUNITION SHIP	20,500	540	81	28.4	2.85	6.67	0.58	0.59	4.58	15
LPD 4	AMPHIBIOUS DOCK	17,000	548.2	82.1	22.0	3.73	6.68	0.60	0.61	3.61	16
AFS 1	COMBAT STORES SHIP	17,500	532	75	25.75	2.91	7.07	0.60	0.61	4.11	17
LST 1179	TANK LANDING SHIP	3500	500	68	15.75	4.32	7.35	0.56	0.57	2.38	18
LSD 36	DOCK LANDING SHIP	14,010	540	84	19.11	4.40	6.42	0.57	0.58	3.11	19
AO 1	REPLENISHMENT OILER	36,700	640	96	32.5	2.95	6.67	0.64	0.65	4.50	20
AD 37	DESTROYER TENDER	24,235	660	85	24	3.54	7.76	0.63	0.64	2.95	21
AOE-1	FAST COMBAT SUPP.	53,600	770	107	39.5	2.70	7.20	0.58	0.62	4.11	22
AS-34	SUBMARINE TENDER	22,250	620	85	24.4	5.48	7.29	0.61	0.62	3.27	23
AKA-113	"	19,230	550	82	26.05	3.15	6.71	0.57	0.59	4.64	24
LHA	AMPHIBIOUS ASSAULT	22,220	700	88	27	3.26	7.95	0.56	0.40	2.25	25
AO-93	OILER	21,890	502	68	30.17	2.25	7.33	0.74	0.76	6.05	26

* C. IS ESTIMATED

M. Rosenblatt & Son, Inc.
DESIGN CALCULATION SHEET

No. 3419
Sheet 2 of 7

Subject

Ship or Project TOWING RESISTANCE

Section

Prepared by RCS

Date 3/13/74 Checked

Reviewed

CALCULATIONS FOR SHIPS USED IN THIS STUDY

SHIP CLASS	DESCRIPTION	DISPL. A LT.	LVL L	BEAM B	DRAFT T	B/T	L/B	C _B	C _P	C _A X 10 ⁻³	CURVE FOR TOWING RESISTANCE	CURVE FOR R _S
CVA(N)65	MINESWEEP CARRIER	35520	1340	133	35.89	3.71	7.82	0.60	0.62	2.66	27	
CVA 59	"	72000	990	129.33	32.65	3.96	7.65	0.60	0.62	2.59	23	
LCU F4	LANDING CRAFT L	375	120.7	29	5.13	5.60	4.16	0.73	0.75	2.46	29	
FF 1052	ESCOR	4200	419	46.6	25	1.36	8.99	0.391	0.32	2.00	30	
DD 52	GUIDED MISSILE DESTROYER	4544	431	47.05	15.3	3.14	9.16	0.52	0.56	1.99	31	
DD 963	DESTROYER	3000	532.2	55	12.74	2.79	9.64	0.49	0.61	1.88	32	
T-A 628		1922	220	46	15	3.07	4.78	0.44	0.45	6.31	33	
DL 6-26	GUIDED MISSILE FRIGATE	7300	524.6	54.4	18.9	2.85	9.64	0.57	0.55	1.92	34	
DD 710	DESTROYER	3480	333	40.89	14.67	2.91	9.37	0.54	0.67	2.12	35	
DL-1	FRIGATE	6625	520	54	18.00	3.0	9.63	0.46	0.57	1.65	36	
LST-1171	TANK LANDING SHIP	7034	426	62	12.29	5.04	6.37	0.76	0.78	3.21	37	
LCC-119	AMPHIBIOUS COMMAND	18500	556	82	26	3.15	6.78	0.55	0.59	3.77	38	
LPH-3	LPH-3	18021	543.02	84.17	26.5	3.18	6.45	0.52	0.57	3.15	39	

* 1. IS ESTIMATED

TABLE - 5
CHARACTERISTICS OF NAVAL VESSELS

CHT. 3 of 7

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	$\frac{B}{T}$	C_D	C_P $\times 10^{-5}$	CURVE FOR HULL RESIS.	CURVE FOR AUGMENTED RESISTANCE
AD-14-19	Destroyer Tender	17176	6200	520	73	25.5	2.86	0.62	4.28	14	9
AD 16	"	16600	4130	465	70	24.0	2.92	0.79	5.78	26	8
AD 23-36	"	18900	4200	465	70	23.5	2.97	0.77	5.88	26	8
AD 37-38	"	21000	5600	613	85	26.0	3.31	0.54	3.12	21	5
ADG 8-10	Deausing Ship	900	1100	180	33	9	3.62	0.57	0.54	13	1
ADG 383	"	1235		215	52	11.0	4.72	0.35	4.34	30	2
AE 4-9	Ammunition Ship	14225	4600	435	63	26.5	2.38	0.51	6.01	26	8
AE 12-19	"	15225	4500	435	63	26.7	2.36	0.51	6.01	26	8
AE 21-25	"	17500	6490	482	72	27.0	2.48	0.41	5.97	13	5
AE 26-35	"	20500		540	81	26.0	2.62	0.33	4.94	15	4
AE 30-31	"	14000	4375	434	63	24.0	2.62	0.53	6.01	26	8
AE 28-29	Stores Ship	15300	4460	445	63	24.5	2.77	0.78	6.1	26	8
AF 42-44	"	7435	2600	320	50	18.0	2.63	0.53	6.01	26	8
AF 48-61	"	15500	4405	445	63	24.5	2.57	0.79	6.16	26	8
T-AF 50-51	"	12800	4375	445	63	22.0	2.47	0.53	4.98	26	8
AF 56-57	"	12130	4100	440	62	22.0	2.47	0.53	4.98	26	8
AF 58-59	"	15540	5400	475	72	28.0	2.57	0.57	5.01	12	5
T-AF 62-64	"	12130	4100	440	62	23.0	2.57	0.57	5.01	12	5
AFS 1-7	Combat Stores Ship	16500	6350	530	79	24	2.7	0.53	4.91	17	4
AG 127	Miscellaneous	2804	1600	322	37	13.7	2.7	0.53	4.91	17	4
AG 153-154	Exper. Navigation Ship	17600	5550	529	76	29.0	2.62	0.53	4.91	17	4
T-AG 162	Exper. Sound Testing	17000		411	61	31.0	2.62	0.53	4.91	17	4
T-AG 164	Hydrographic Research	12450	4340	437	62	24.0	2.62	0.53	4.91	17	4
T-AG 165-171	Special Mission	7460	2600	320	50	19.0	2.62	0.53	4.91	17	4
T-AG 172-174	Cargo	12400	4100	440	62	24.0	2.62	0.53	4.91	17	4
T-AG 175	Surveying Ship	7400	2600	320	50	21.0	3.11	0.71	7.5	26	8
AG 176	Miscellaneous			215	32	10.5	3.11	0.71	7.5	26	8
T-AG 178	Hydrographic Research	11000	4375	440	63	24.5	3.33	0.71	7.5	26	8
AG 191	Sonar Test Ship	8200	2600	530	53	25.0	2.11	0.41	4.92	26	8
AG 332	Cargo	1095	990	177	33	7.5	3.62	0.71	7.5	26	8
AGDE 1	Escort Research	3426	1715	371	44	24.0	1.83	0.69	0.71	10	4
AGF 1	Misc. Command Ship	2800	1600	390	41	13.0	3.75	0.41	4.92	26	8
T-AGM 1-11	Missile Range Test Ship	11100	4100	444	62	22.0	2.81	0.61	4.93	26	8
T-AGM 2	"	550		32	32	11.5				17	4
T-AGM 9-10	"	16600	4900	528	72	26.0				17	4
T-AGM 13-16	"	7460	2600	320	50	19.0				26	8
T-AGM 19-21	"	21626	5020	577	73	25.0	3.0	0.70	6.71	27	9
AGMR 1	Communications Relay	22500	5525	575	75					15	4
AGMR 2	"	19600	6000	664	78	25.3	3.04	0.51	6.53	27	9
AGTR 1-3	Technical Research	11365	3250	416	57	32.0	2.57	0.76	5.92	26	8
AGTR 4-5	"	10680	4100	440	62	24				13	5
AH 16-17	Hospital Ship	15900	4900	496	72	23.4	3.08	0.68	4.94	17	4
T-AK 180-250	Cargo Ship	7450	3100	320	50	19.4				26	8
T-AK 237-276	"	12450	4100	437	62	24				13	5
T-AK 241-254	"	12400	4100	437	62	24				13	5
T-AK 255-267	"	4900	4100	528	72	33	2.10	0.73		17	4
AK 260	"	12420	4100	437	62	24				13	5

* C_P IS ESTIMATED
+ ACTUAL CALCULATION PERFORMED

TABLE 5 (CONT'D)

CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	D/T	L/B	C _B	C _P	C _V	CURVE FOR HULL RESIS.	CURVE ADDED RESIS.
T-AK 271	Cargo Ship	4942		257	52	18.7	2.78	4.74	0.69	0.71	10.18	26	2
T-AK 272	"	15800	5400	465	46	24.0	2.27	2.04	0.66	0.63	5.5	13	8
T-AK 273-281	"	11150	4100	435	62	22.0	2.82	2.02	0.66	0.67	4.74	20	8
T-AK 283	"	14000	4375	475	63	24	2.63	2.06	0.73	0.73	5.56	15	8
T-AK 1	Dock Cargo Ship	14094	6856	475	78	22	3.55	1.67	0.73	0.75	4.60	26	8
T-AK 7	Vehicle Cargo Ship	18150		465	78	29.0	2.63	5.34	0.65	0.63	6.32	13	8
T-AK 9	"	21700		475	83	23.0	2.96	6.03	0.65	0.64	6.03	20	9
T-AKV 8-37	Cargo/Aircraft Ferry	24560	5400	525	75	32.0	2.74	7.0	0.68	0.70	5.74	20	9
T-AKV 40-43	"	15700	5340	465	70	26	2.63	6.64	0.65	0.66	5.77	13	8
AO 24-53	Oilier	25400-34700	5540	625/620	75	31.5/35	2.2	7.18	0.71	0.75	6.58	26	5
AO 36-47	"	21850	4290	488	68	24.7	2.2	7.18	0.71	0.75	6.58	26	5
T-AO 49-142	"	22380	4610	503	68	20.8	2.21	7.40	0.74	0.75	6.15	26	9
AO 105-109	"	34750	5480	620	75	35.5	2.11	7.21	0.74	0.75	5.10	26	5
AO 143-148	"	38000	6300	640	86	35.1	2.95	7.94	0.65	0.70	5.07	26	5
T-AO 149-152	"			591	83	7							
T-AO 165	"			591	80	7							
AOE 1-5	Fast Combat Support	53600	9750	770	107	39						22	6
AOG 1-56	Gasoline Tanker	4570	2200	332	49	16.1	3.04	5.36	0.69	0.67	6.32	26	2
T-AOG 77-80	"	6000		325	48	18.0	2.52	5.77	0.71	0.72	6.12	26	2
T-AOG 81-82	"	5720		317	46	12.0	2.74	6.46	0.60	0.61	4.66	20	5
AOR 1-6	Replenishment Oilier	38100	7590	659	96	35	2.74	6.46	0.60	0.61	4.66	20	5
T-AP 110-119	Transport	20175	6800	573	76	25.5	2.38	7.57	0.64	0.65	5.25	23	9
T-AP 122-127	"	20620		573	76	25.5							
T-AP 196-198	"	19600		500	73	28.6	2.97	6.85	0.63	0.65	5.79	13	9
APB 35-48	Self-Propelled Barracks	4080	1910	316	50	19.2	2.90	6.52	0.70	0.70	4.52	26	4
APC 116	Coastal Transport	7460	2600	320	50	13.0	2.78	6.4	0.61	0.63	7.97	26	4
APL 2-58	Barracks Barges	2660		317	49	3.5							
AR 5-8	Repair Ship	16130	5460	520	73	25.2	3.15	2.12	0.67	0.65	4.02	14	9
AR 9-12	"	14500	4100	445	70	24.0	2.92	6.64	0.65	0.65	5.05	20	9
AR 13-14	"	14490	4200	445	70	28.0	2.50	6.54	0.58	0.57	5.01	15	9
AR 22-23	"	16900	4180	465	70	23.8	2.94	6.64	0.74	0.76	5.88	26	8
ARB 4-8	Battle Damage Repair	4080	2320	316	50	14.0	4.55	6.35	0.61	0.63	7.52	37	4
ARC 2-6	Cable Repair Ship	7380		322	47	14	2.61	6.87	0.65	0.66	7.74	26	4
ARC 3-4	"	7080		400	69	16.0	4.0	6.55	0.60	0.62	2.97	19	8
ARG 4	Engine Repair Ship	14350	3250	416	57	23.0	2.18	7.37	0.72	0.73	6.38	26	8
ARL 1-38	Landing Craft Repair	3830	2320	316	50	10.6	4.72	6.32	0.60	0.62	4.34	37	2
ARS 6-43	Salvage Ship	1900	1500	207	39	13.0	3.0	5.31	0.61	0.65	7.45	26	1
ARSD 1-2	Salvage Lift Ship	1095	990	197	34	7.0	4.66	6.79	0.62	0.63	5.01	26	1
ARST 1-2	Salvage Craft Tender	4080	2320	316	50	11.0	4.55	6.35	0.61	0.63	7.52	26	4
ARVA 5-6	Aircraft Airframe Rpr.	4080	2320	316	50	11.0	4.55	6.35	0.61	0.63	7.52	26	4
ARVE 4	Aircraft Engine Repair	4080	2320	316	50	11.0	4.55	6.35	0.61	0.63	7.52	26	4
T-ARVH 1	Helicopter Repair Ship	13475	5100	503	68	21	3.87	7.36	0.63	0.65	3.60	21	9
AS 13-14	Submarine Tender	14500	4130	465	70	24	2.52	6.54	0.65	0.65	5.05	20	8
AS 11-18	"	18000	6200	520	73	24.5	2.18	7.21	0.68	0.68	5.78	37	9
AS 19	"	18500	6200	544	73	24.5	2.18	7.21	0.68	0.68	5.78	37	9
AS 22	"	15400	4300	465	70	25.0	2.0	6.64	0.66	0.68	5.36	26	8
AS 23	"	16100	4300	465	70	22.7	3.08	6.64	0.76	0.78	5.60	26	8

* C_P " ESTIMATEDC_P = 0.67C_P = 0.67

SHT. 4 OF 7

TABLE - 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

SMT. 5 OF 7

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	1/2	C _B	C _P	C _D	CURVE FOR HULL RESIS.	CURVE FOR ADDED RESISTANCE	
AS 31-32	Submarine Tender	18300	6440	570	83	24	2.4	1.87	0.53	3.44	12	R	
AS 33-34	"	22250	7550	626	85	24					23	5	
AS 35-37	"	22640	7550	626	85	24.1					23	5	
ASR 7-16	Submarine Rescue	2290	1200	140	42	14.4	5.71	0.56	0.47	5.8	21	7	
ASR 12-20	"	1760	1170	175	39	15.3	5.0	0.5	0.4	6.31	18	7	
ASR 21-22	"	3411			86								
AV 7-13	Seaplane Tender	15090	5100	520	69	22.2	2.8	2.57	0.55	3.26	17	9	
AV 10	"	14200	5500	465	70	22.4	2.7	2.64	0.54	3.21	20	9	
AVB 2	Advanced Avia:ion Base	6000	3940	348	54	12.9	4.1	6.81	0.82	0.84	37	4	
AVM 1	Guided Missile Ship	15170	5300	540	72	26.3	3.55	2.22	0.71	3.78	37	5	
AVT 2-5	Aircraft Transport	15800	6000	600	72	26.0	3.77	2.35	0.71	3.50	37	5	
AVT 9	Electronics Test Ship	38500	8300	810	102	31.0	3.21	8.04	0.57	0.53	2.34	10	6
AV 4	Distilling Ship	22380	4600	523	68	30.8	2.41	7.40	0.77	0.76	3.15	26	9
BB 61-64	Battleship	59000	8500	860	108	36.2	3.38	7.26	0.51	0.46	3.24	14	6
CA 68-130	Heavy Cruiser	17500	5300	664	71	24.0	2.36	9.35	0.57	0.58	2.07	7	7
CA 122-124	"	17500	5300	664	71	24.5					7	7	
CA 134-148	"	21470	4500	700	74	24.0					7	7	
CC 1	Command Ship	17200	5300	664	71	24.0					7	7	
CC 2	"	19600	6000	664	71	24.0					7	7	
CG 10-12	Guided Missile Cruiser	17700	6300	664	71	26.0	2.73	9.35	0.57	0.53	2.12	6	7
CGN 9	"	17350	7900	639	74	27.0					6	7	
CL 65-103	Light Cruiser	13755	4300	600	66	25.0	2.69	9.09	0.55	0.57	2.22	4	5
CL 106	"	14055	4300	600	66	25.1					4	5	
CL 144-145	"	18700	5000	664	71	25.0	2.89	9.35	0.55	0.60	2.24	7	7
CLG 3-8	Guided Missile LtCruiser	14600	4000	600	66	25.0	2.64	9.09	0.55	0.53	2.37	7	5
CVA 14-34	Attack Aircraft Carrier	42600	8300	820	103	31.0	3.21	7.76	0.57	0.61	2.70	27	6
CVA 41-43	"	62000		900	121	36.0	3.6	7.44	0.55	0.61	2.38	27	6
CVA 59-62	"	78040	13100	930	130	35.8	3.43	7.62	0.57	0.67	2.32	28	6
CVA 61	"	75200	13100	970	130	37.0	3.51	7.62	0.55	0.58	2.71	28	6
CVA 64	"	75200	13100	970	130	37.0					28	6	
CVA 66	"	78250	13100	970	130	37.0					28	6	
CVA 67	"	83000	13100	970	130	37.0					28	6	
CVAH 65	"	83350	16600	1040	133	37.0					27	6	
CVAH 68-70	"	95100		1040	134						27	6	
CVS 9-39	ASW Aircraft Carrier	41000	8300	820	102	30.3					27	6	
CVT 16	Training Carrier	41000	8300	820	102	30.3					27	6	
DD 422-617	Destroyer	2575	1400	341	36	14.0	3.57	0.57	0.46	2.27	3	2	
DD 423-647	"	2590	1400	341	36	14.0					3	2	
DD 445-795	"	3040	1400	369	40	14.1	3.87	0.53	0.43	2.12	35	2	
DD 692-857	"	3400	1400	369	41	14.5					35	2	
DD 710-890	"	3540	1450	383	41	14.5					35	2	
DD 712	"	3480	1450	383	41	14.5					35	2	
DD 719-824	"	3500	1450	383	41	14.5					35	2	
DD 825-827	"	3410	1450	383	41	14.5					35	2	
DD 931-951	"	4200	2100	407	44	15.0					32	2	
DD 963-967	"	7000									32	2	

* C_P IS ESTIMATED

TABLE - 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

SHT. 6 OF 7

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	Y/B	C _B	C _P	C _V	CURVE HULL RESIS.	CURVE FOR ADDED RESISTANCE
DDG 2-24	Guided Missile Destroyer	4500	2256	431	47	20.0	2.35	9.17	0.35	0.72	1.97	31	8
DDG 31-34	"	4200	2100	407	44	15.0	3.33	9.25	0.55	0.61	2.18	35	4
DDG 35-36	"	4730	2800	476	50	26.0	1.52	9.32	0.27	0.35	1.53	30	6
DE 129-399	Escort Ship	1990	1400	300	37	12.0	2.47	8.11	0.57	0.65	2.58	35	4
DE 162-767	"	2230	1200	300	37	14.0	2.44	8.11	0.55	0.55	2.29	35	4
DE 202-800	"	2230	1200	300	37	14.0	"	"	"	"	"	35	4
DE 224-708	"	2230	1200	300	37	14.0	"	"	"	"	"	35	4
DE 339-538	"	2100	1200	300	37	14.0	"	"	"	"	"	35	4
DE 1006-1037	"	1914	1342	308	37	12.0	3.16	8.11	0.27	0.37	1.54	1	4
DE 1033-1036	"	1750	1340	303	37	12.0	3.09	8.32	0.47	0.61	2.24	1	4
DE 1037-1038	"	2650	1715	350	44	23.0	2.06	8.11	0.32	0.37	2.20	1	4
DE 1040-1051	"	3400	1715	391	44	24.0	1.83	8.32	0.29	0.37	1.99	2	4
DE 1052-1027	"	4100	2020	419	47	25.7	1.68	8.32	0.27	0.35	1.75	30	4
DER 1-6	Guided Missile Escorts	3600	1715	371	44	24.0	1.83	8.32	0.27	0.37	1.99	2	4
DER 147-400	Radar Picket Escorts	1850	1400	300	37	11.0	3.26	8.11	0.53	0.59	2.40	1	2
DER 539-540	"	2100	1400	300	37	11.0	"	"	"	"	"	1	2
DL 1	Frigate	7300	2600	520	54	19.0	2.84	8.63	0.48	0.49	1.82	36	3
DL 4-5	"	6730	2800	476	52	26.0	1.72	9.32	0.37	0.39	1.53	30	3
DLG 6-15	Guided Missile Frigate	5800	513	513	54	19	2.6	8.63	0.48	0.49	1.50	32	3
DLG 16-24	"	7800	3675	525	54	20.0	2.25	9.35	0.42	0.52	1.32	34	3
DLG 26-34	"	7930	3040	550	58	25.0	1.35	1.12	0.38	0.40	1.80	5	3
DLGH 25	"	8580	2960	550	58	26.0	"	"	"	"	"	5	3
DLGH 35	"	9200	2960	550	58	26.0	"	"	"	"	"	5	3
DLGH 36-37	"	10150	2960	550	58	26.0	"	"	"	"	"	5	3
DLGH 38-41	"	10000	2960	550	58	26.0	"	"	"	"	"	5	3
IX 21	Sail Frigate	2200											
IX 304	Experimental Target	13755	4300	600	66	25.0	2.64	9.09	0.49	0.50	2.32	7	5
LCC 7-17	Amphibious Command	12560	4300	435	63	22.0	2.86	6.90	0.72	0.74	5.34	26	8
LCC 19-20	"	17100	580	580	82	27.0	3.04	7.07	0.47	0.42	3.07	30	3
LHA 1-3	Amphibious Assault Ship	40000	8800	755	106	24.4	2.63	6.90	0.72	0.74	5.35	26	8
LKA 19-97	Amphibious Cargo Ship	14000	4300	435	63	22.4	2.81	6.90	0.64	0.61	6.02	26	8
LKA 103-108	"	14160	4300	435	63	22.4	2.81	6.90	0.64	0.61	6.02	26	8
LKA 112	"	15970	4900	528	76	26.0	2.32	6.95	0.59	0.55	3.80	12	9
LKA 113-117	"	20700	5400	465	70	25.5	2.37	6.67	0.61	0.62	5.31	13	8
LPA 32-44	Amphibious Transport	15200	4100	437	62	27.0	2.58	7.05	0.56	0.58	4.39	13	8
LPA 194-237	"	10470	4900	578	76	25.0	3.04	6.95	0.59	0.60	4.00	14	9
LPA 248-249	"	16840	6050	520	84	21.0	4.0	5.15	0.51	0.52	3.78	12	9
LPD 1-3	Dock	13500	6050	578	84	23.0	3.65	6.22	0.58	0.57	3.59	16	9
LPD 4-15	Dock	16900	6050	578	84	23.0	3.65	6.22	0.58	0.57	3.59	16	9
LPN 2-12	Amphibious Assault Ship	18300	8300	556	84	24.0	3.23	6.62	0.53	0.57	3.73	37	7
LPN 4-8	"	40600	8300	820	93	31.0	3.0	5.82	0.60	0.61	2.88	28	6
LPR 55-135	Amphibious Trans. Small	2130	1400	300	37	13.0	2.85	8.11	0.52	0.53	2.74	1	2
LPSS 315	Amphibious Trans. Sub.	2035	450	367	27	17.0	1.53	11.37	0.51	0.52	2.47	30	2
LPSS 574	"	2620	4100	454	30	17.3	"	"	"	"	"	30	2
LSD 1-7	Dock Landing Ship	8700	4100	454	72.0	12.0	4.24	6.31	0.35	0.56	3.25	17	8
LSD 13-27	"	9375	472	472	76.0	18.0	4.22	6.21	0.51	0.51	3.12	19	8
LSD 28-35	"	11270	5695	500	84	18.0	4.67	5.95	0.52	0.53	3.16	19	7
LSD 36-40	"	13650	5700	544	84	18.0	"	"	"	"	"	19	7

* C_P IS ESTIMATED

TABLE - 5 (CONT'D)
CHARACTERISTICS OF NAVAL VESSELS

CLASS	DESCRIPTION	DISPLACEMENT (L. TONS)	LIGHT SHIP FRONTAL WINDAGE AREA (SQ. FT.)	LENGTH LWL L	BEAM B	DRAFT T	B/T	L/B	C _B	C _P	C _V	CURVE FOR HULL RESIST.	CURVE FOR ADDED RESIST.
T-LST47-1088	Tank Landing Ship	4080	2000	316	50	11.0	4.55	6.32	0.82	0.83	4.53	37	2
LST 334-509	"	4080	2000	316	50	11.0	"	"	"	"	"	37	2
LST 515-1150	"	4080	2000	316	50	11.0	"	"	"	"	"	37	2
LST 1153	"	6000	3940	368	54	12.9	4.13	6.81	0.82	0.83	4.21	37	4
LST1156-1170	"	5800	3940	368	55	12.9	"	"	"	"	"	37	4
LST1171-1178	"	8000	3400	426	62	13.3	4.66	6.37	0.80	0.81	3.62	377	8
LST1179-1198	"	8342	"	509	70	15.0	"	"	"	"	"	184	9
MCS 1-2	Mine Counter Measures	9040	4230	440	60	10	3.0	7.33	0.60	0.61	3.71	16	3
MHC 43	Coastal Mine Hunter	"	"	130	25	6.3	3.01	5.2	"	"	"	"	4
MHD 23-33	Fast Minelayers	3320	1400	369	41	14.4	2.95	9.0	0.57	0.54	2.31	35	4
MHF 5	Fleet Minelayer	8680	"	440	60	14.9	3.03	7.33	0.53	0.51	3.37	11	8

* C_P IS ESTIMATED

APPENDIX E

CORRELATION STUDY

DESIGN CALCULATION SHEET

no. 5711

Sheet of

Subject USE OF FULL SCALE TOWING TESTS FOR CORRELATION

Ship or Project TOW RESISTANCE

Section _____ Prepared by RCS

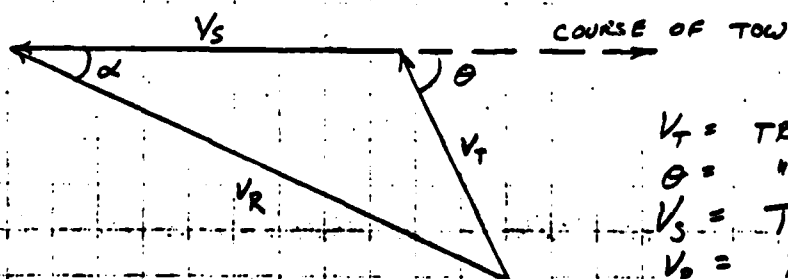
Date 3/15/76 Checked _____

Reviewed _____

DATA FROM THE TOWING TEST REPORT OF THE LST 1179 CLASS (REF. 28) WAS EXAMINED IN ORDER TO CORRELATE FULL SCALE TEST RESULTS WITH THE RESULTS OBTAINED FROM THE CALCULATION PROCEDURE DEVELOPED IN THIS STUDY AND WITH THE CALCULATION PROCEDURE OF THE U.S. NAVY TOWING MANUAL.

ALTHOUGH SEVERAL FULL SCALE TESTS WERE CONDUCTED, ONLY 2 TESTS WERE SELECTED FOR STUDY SINCE THE OTHERS WERE CONDUCTED IN CONDITIONS WHICH COULD NOT BE DIRECTLY CORRELATED WITH THE TWO EMPIRICAL METHODS OF CALCULATION, SINCE THE TOW WAS UNDERGOING A TURN OR RUDDERS OF THE TOW WERE SPAYED. ALTHOUGH THE SHAFTS WERE NOT LOCKED, THE FRICTION OF THE SHAFT BEARINGS WAS SUFFICIENT TO PREVENT ROTATION, SO FOR PRACTICAL PURPOSES THE SHAFTS CAN BE CONSIDERED LOCKED.

IN ORDER TO COMPARE THE TEST RESULTS WITH THE MR'S CALCULATION PROCEDURE, TRUE WIND VELOCITY AND DIRECTION WERE CONVERTED TO RELATIVE WIND VELOCITY AND DIRECTION BY THE FOLLOWING CALCULATIONS:



V_t = TRUE WIND SPEED

θ = " " DIRECTION

V_s = TOW SPEED

V_r = RELATIVE WIND SPEED

α = " " DIRECTION

DESIGN CALCULATION SHEET

Subject USE OF FULL SCALE TOWING TESTS FOR CORRELATIONShip or Project TOW RESISTANCE

Section

Prepared by RCSDate 3/15/76 Checked

Reviewed

$$V_R = \sqrt{V_S^2 + V_T^2 - 2(V_S)(V_T) \cos(180 - \theta)}$$

$$\sin \alpha = \frac{V_T \sin(180 - \theta)}{V_R}$$

$$\alpha = \sin^{-1} \left(\frac{V_T \sin(180 - \theta)}{V_R} \right) \quad (\text{IF } \theta < 90^\circ)$$

$$\alpha = 180 - \left[\sin^{-1} \left(\frac{V_S \sin(180 - \theta)}{V_R} \right) + (180 - \theta) \right] \quad (\text{IF } \theta > 90^\circ)$$

CALCULATIONS FOR TEST #1

$$V_R = (9.5^2 + 12^2 - 2(9.5)(12) \cos(180 - 5))^{1/2}$$

$$V_R = 21.48 \text{ KT.}$$

$$\alpha = \sin^{-1} \frac{12 \sin(180 - 5)}{21.48}$$

$$\alpha \approx 3^\circ$$

CALCULATIONS FOR TEST #2

$$V_R = [9^2 + 10^2 - 2(9)(10) \cos(180 - 176)]^{1/2}$$

$$= 1.44 \text{ KT.}$$

$$\alpha = 180 - \left[\sin^{-1} \left(\frac{1.44 \sin(180 - 176)}{9} \right) + 4 \right]$$

$$\approx 175.36^\circ$$

DESIGN CALCULATION SHEET

no. 5717

Sheet of

 Subject USE OF FULL SCALE TOWING TESTS FOR CORRELATION

 Ship or Project TOW RESISTANCE

Section

 Prepared by R.C.S.

 Date 3/15/76

Checked

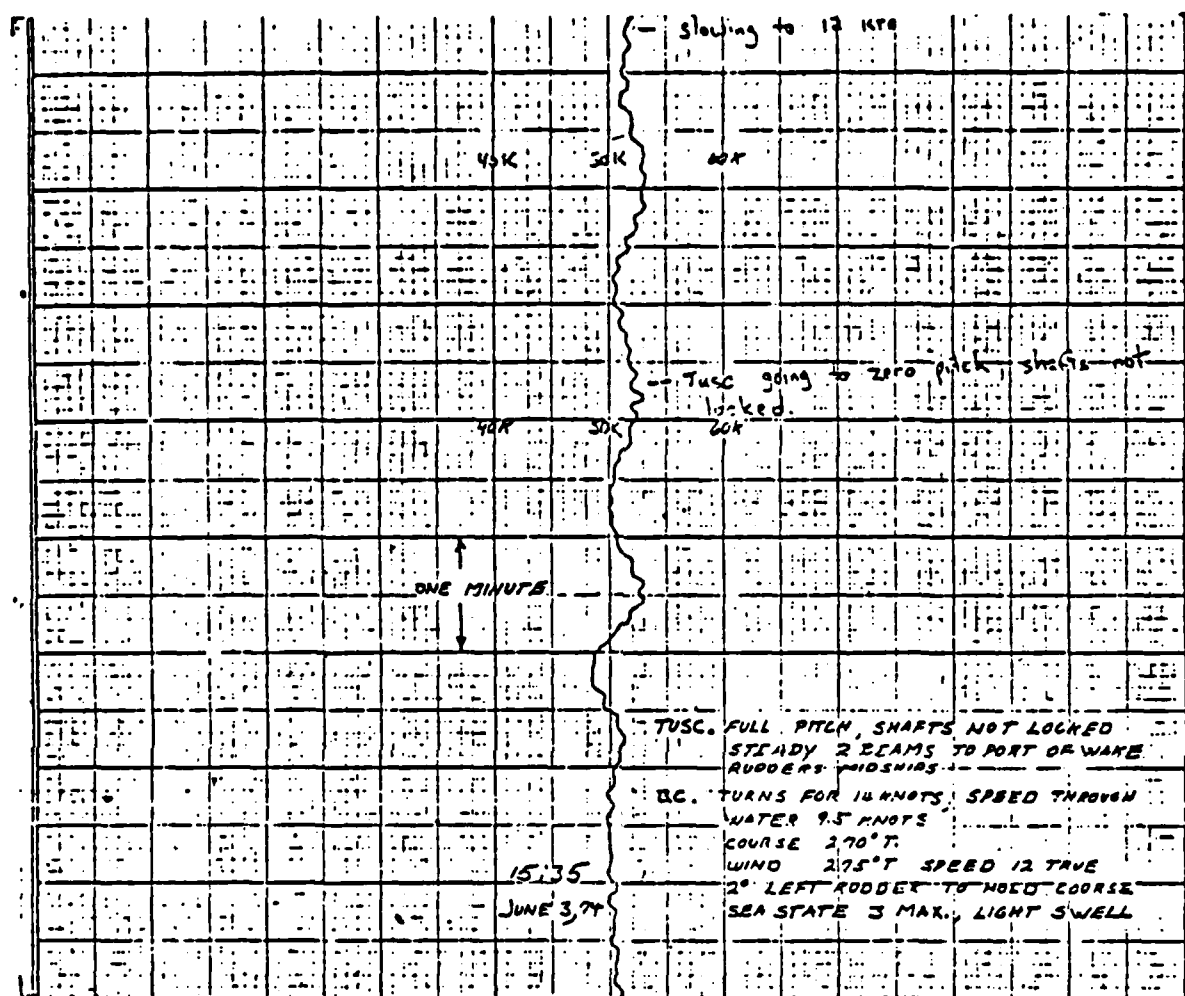
Reviewed

SUMMARY OF RESULTS FOR TESTS #1 & #2 OF LST 1179 CLASS

TEST No.	TOW SPEED KT.	REL WIND SPEED KT.	REL WIND DIR. DEG.	MEASURED TOW RESIS. LST 1187 TEST (AVERAGE)	MR&S CALC. TOW RESIS.		U.S.N. CALC. TOW RESIS.	
					LB.	% DIFF	LB.	% DIFF
#1	9.5	21.48	3°	51,000	74,234	45%	108,946	114%
#2	9	1.44	175	48,000	60,990	27%	92,263	92.2%

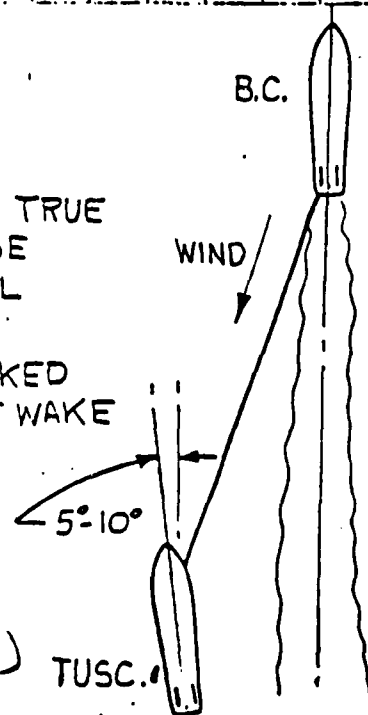
TEST #1

TOWING AT HIGH SPEED, STRAIGHT COURSE



B.C. TURNS FOR 14 KNOTS
 PIT LOG- 9.5 KNOTS
 6-ENGINES
 COURSE 270° T
 WIND 275° T SPEED 12 KNOTS TRUE
 2° LEFT RUDDER TO HOLD COURSE
 SEA STATE 3 MAX, LIGHT SWELL

TUSC. FULL PITCH, SHAFTS NOT LOCKED
 STEADY 2 BEAMS TO PORT OF WAKE
 RUDDERS 0 DEGREES



FIGURE

(REF. 28)

TUSC.

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 - TEST 1

DATE: 3/12/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST 1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3940 *
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.48
11	RELATIVE WIND DIRECTION, α	DEGREES	3°
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	9.5
15	R_H/Δ (SEE FIG. 17)	—	2.86
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	29823
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	36472
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	6437
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	74234

- NOTES:
- 1) ASSUME A_T IS SAME AS LST 1156.
 - 2) TRUE WIND SPEED = 12 KT.
 - 3) TRUE WIND DIRECTION = 275°, COURSE = 270° T
 - 4) SHAFTS NOT LOCKED

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179 - TEST #1

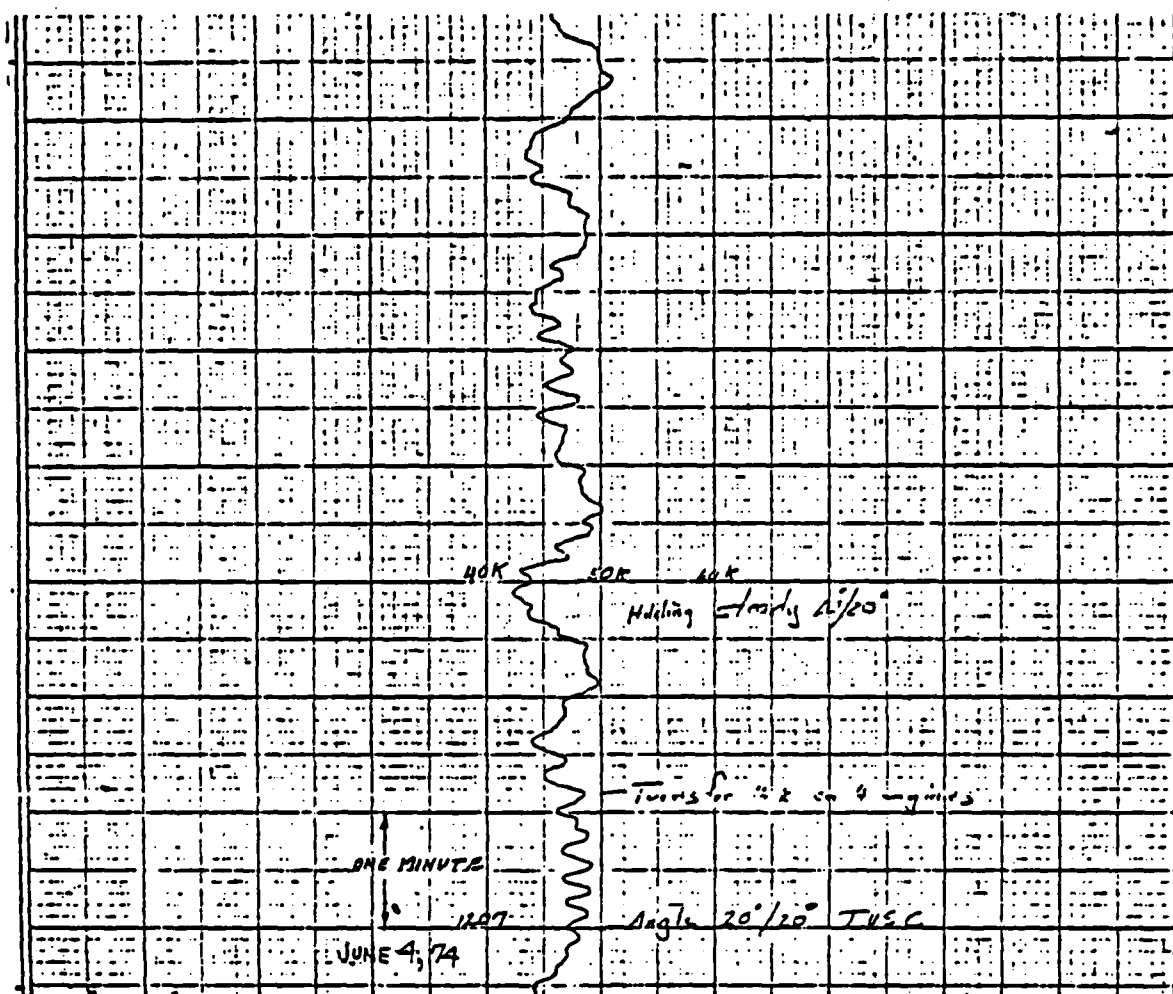
DATE: 3/12/76

BY: 12CS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>LST-1179</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>8342</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>3940</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>9.5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>5°</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>12</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>21.45</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0.6</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>5005</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>8.9</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>103941</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>108.14</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>33124</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>41120</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>29697</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>108946</u>

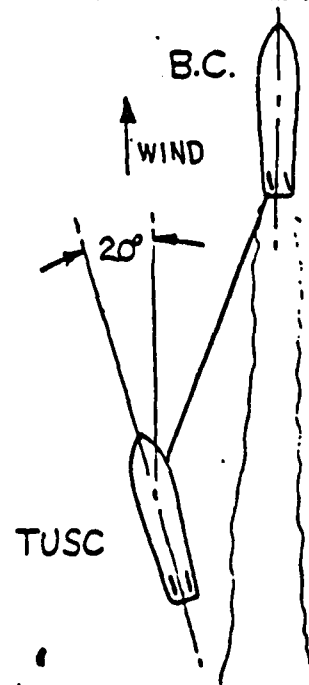
TEST #2

URNS FOR 14 KNOTS DOWN WIND



B.C. TURNS FOR 14 KNOTS
 PIT LOG 9 KNOTS
 4 ENGINES
 COURSE 070°T
 WIND 254°T SPEED 10 KNOTS TRUE
 SEA STATE 3 MAX LIGHT SWELL
 RUDDER 4° LEFT TO HOLD COURSE

TUSC FULL PITCH, SHAFTS NOT LOCKED
 RUDDERS 0 DEGREES



FIGURE

(REF. 28)

CALCULATION OF TOWING RESISTANCE

SHIP: LST 1179 TEST #2 DATE: 3/12/76
 BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST 1179
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	3940
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	108.14
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	18
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	9
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	1.44 KT.
11	RELATIVE WIND DIRECTION, α	DEGREES	175
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	-1.47
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	9
15	R_H/Δ (SEE FIG. 17)	—	2.57
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	26799
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	32734
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	-42.5
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	60990

- NOTES : 1) ASSUME A_T IS SAME AS LST 1156
 2) TRUE WIND SPEED = 10 KT.
 3) TRUE WIND DIRECTION = 254°; COURSE = 070° T $\theta = 18$
 4) SHAFTS NOT LOCKED

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: LST 1179 - TEST #2

DATE: 3/15/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		LST 1179
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	8342
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	3940
4	TOW SPEED, V_{TOW}	KNOTS	9
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	176
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	10
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	-1.0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	≈ 0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	≈ 0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	7.9
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	92263
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	108.14
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	29729
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	36173
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	26361
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	72263

DESIGN CALCULATION SHEET

No. 2111

Sheet of

Subject CORRELATION STUDY COMPARING U.S. NAVY TOWING MANUAL WITH MR&S METHOD

Ship or Project TOWING RESISTANCE CRITERIA

Section BSDD

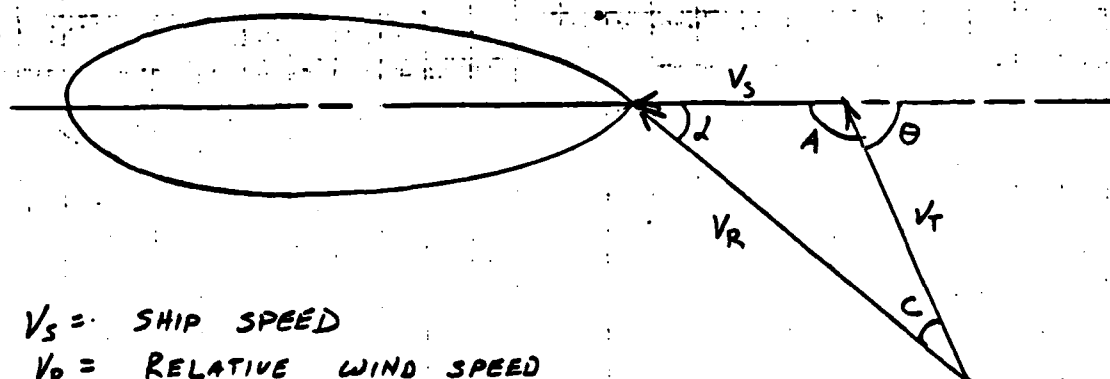
Prepared by R.C.S.

Date 3/1/76 Checked

Reviewed

THE FOLLOWING STUDY COMPARES THE RESULTS OF A SERIES OF TOW RESISTANCE CALCULATIONS USING THE U.S. NAVY TOWING MANUAL (DATE 1971) AND THE MR&S METHOD DEVELOPED IN THIS REPORT.

THE U.S. NAVY CALCULATION PROCEDURE USES THE TRUE WIND VELOCITY AND DIRECTION RELATIVE TO THE SHIP COURSE WHILE THE MR&S METHOD USES A RELATIVE WIND VELOCITY AND RELATIVE (OR APPARENT) WIND DIRECTION. TO INSURE THAT EQUIVALENT WEATHER CONDITIONS WERE USED FOR THE TWO METHODS, A TRUE WIND STRENGTH AND RELATIVE WIND DIRECTION WERE SELECTED AND A TRUE WIND DIRECTION AND RELATIVE WIND VELOCITY WERE CALCULATED.

VECTOR DIAGRAM

 $V_S = \text{SHIP SPEED}$
 $V_R = \text{RELATIVE WIND SPEED}$
 $V_T = \text{TRUE WIND SPEED}$

$$\sin(C) = \frac{V_S \sin \alpha}{V_T}$$

$$A = 180^\circ - C - \alpha$$

$$V_R = \frac{V_T \sin A}{\sin \alpha}$$

$$\theta = \alpha + C$$

Subject CORRELATION STUDY COMPARING U.S.N. TOWING MANUAL WITH MR45 METHOD

Ship or Project TOWING RESISTANCE CRITERIA

Section

Prepared by

RCS

Date 3/1/76

Checked

Reviewed

CONDITIONS CHOSEN FOR CORRELATION STUDY

BEAUFORT No.	SHIP SPEED KT.	RELATIVE WIND		TRUE WIND	
		α (DEG.)	V_R (KT.)	θ (DEG.)	V_T (KT.)
0	10	0	10	0	0
4	8	0	21.5	0	13.5
	8	30	19.82	47.23	13.5
	8	90	10.87	126.34	13.5
6	5	0	29.5	0	24.5
	5	30	28.7	35.86	24.5
	5	90	23.98	101.8	24.5

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF -148 OCEAN TUG

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>ATF 148</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>1675</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>1200</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>0</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>10</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0.3</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>360</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>9.8*</u>
11	SEA STATE CORRECTION FACTOR K_s , (SEE TABLE 8)	--	<u>1.0</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>16,415</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>43</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>14594</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>1821</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>0</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>16775</u>

* NOTE : USED LST CURVE TO OBTAIN r_H SO
A POSITIVE HULL RESISTANCE COULD BE ATTAINED.

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF-148 OCEAN TUG

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>ATF 148</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>1675</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>1200</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>21.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0.9</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>1080</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>6.3</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>14774</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>43</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>9340</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>1213</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>4221</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>15854</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	47.23
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	17.17
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0.7
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	840
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	14774
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	43
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	9340
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	1213
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	4221
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	15614

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1200
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	6.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	14774
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	43
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	9340
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	1213
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	4221
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	14774

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: <u>ATF-148</u>		DATE: <u>2/25/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>ATF-148</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>1675</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>1200</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>29.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>2848</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.8</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>2144</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>43</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>3649</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>-2309*</u> ?
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>—</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>—</u>

NOTE : EVEN USING LST CURVE PRODUCES A
NEGATIVE HULL RESISTANCE.

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	R_H/Δ (SEE FIG. 17)	—	7.1
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	14866
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	16053
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	455
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	31372

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	7035
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	10284
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	2105
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	20324

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	7035
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	10284
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	2105
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	20324

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1625
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.1
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	7035
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	10284
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	53.81
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	18273

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.1
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	7035
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	10284
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	53.81
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	18273

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.1
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	900
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	7035
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	10284
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	53.81
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	18273

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: JCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.13
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	23,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	1.75
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	3664
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	4017
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	4239
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	35419

CALCULATION OF TOWING RESISTANCE

SHIP: ATF-148

DATE: 2/25/76

BY: JCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		ATF-148
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	1675
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1200
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	43
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	9
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	2
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.13
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	23,500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	1.75
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	3664
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	4017
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	4239
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	35419

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1 FAST COMBAT SUPPORT

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>0</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>10</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ.FT.	<u>0.3</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>2925</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>3.5</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.0</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>187600</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>154766</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>32834</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>0</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>190525</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1 FAST COMBAT SUPPORT

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>0</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>10</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0.3</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>2925</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>3.5</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.0</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>187600</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>154766</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>32834</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>0</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>190525</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>47.23</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>17.17</u>
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	<u>0.5</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>4875</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.2</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>165088</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>99050</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>18870</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>47168</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>169963</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>47.23</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>17.17</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0.5</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>4875</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.2</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>165088</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>99050</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>18870</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>47168</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>169963</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>29.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>29.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>16575</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.8</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>68608</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>38692</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>4188</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>25728</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>85183</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>29.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>29.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>16575</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.8</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>68608</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>38692</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>4188</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>25728</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>85183</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>101.8</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>-0.21</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>0</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.8</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>68608</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>38692</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>4183</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>2572.9</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>68608</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>53,500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>9750</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>101.8</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>-0.21</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>0</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.8</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>68608</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_P	SQ. FT.	<u>456</u>
14	PROPELLER RESISTANCE = $R_P = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>38692</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>4188</u>
16	SEA STATE RESISTANCE = $R_S = (12) - (15) - (14)$	POUNDS	<u>25728</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>68608</u>

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	53,600
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	77050
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	109061
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	17103
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	.

TABLE - 6
CALCULATION OF TOWING RESISTANCE

SHIP: <u>AOE-1</u>		DATE: <u>2/26/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	53,600
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	77050
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	109061
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	17103
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	53,600
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.37
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	77050
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	109061
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	373
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	187804

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	53,600
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.15
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	77050
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	109061
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	393
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	187804

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	<u>53,600</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>9750</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.75</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>456</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>22</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>1</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>6</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>23.98</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>90</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>0.09</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>44,000</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>0.52</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>77050</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>42602</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>1915</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>165567</u>

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	53,600
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	9750
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	456
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	22
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	6
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.09
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	44,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.52
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	77050
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	42602
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	1915
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	165567

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: A02-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		A02-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	10
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	0
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	10
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0.3
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	2277
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	5.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.0
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	133350
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	274
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	92996
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	40354
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	0
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	125627

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: 2000-1

DATE: 2/24/74

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>2000-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>5800</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>7570</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>17.23</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>17.17</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>2.5</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>3795</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.2</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>117342</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>279</u>
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>72517</u>
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	<u>24303</u>
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	<u>32522</u>
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	<u>121143</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOR-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOR-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>38100</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>7590</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>29.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>15180</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.7</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>47672</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>774</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>23249</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>3421</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>16002</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>63672</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AOR-1

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOR-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	29.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	1.7
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	17900
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	47472
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	274
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	23249
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	3421
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	16002
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	65572

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AGE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AGE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>38100</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>7590</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>101.8</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>21.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>-2.01</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>0</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.7</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>42272</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>74</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>23249</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>3421</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>14022</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>42672</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AGE-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AGE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	38100
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	7590
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	101.3
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	-0.01
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	0.7
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	47572
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	74
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	23249
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	3421
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	16022
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	42672

CALCULATION OF TOWING RESISTANCE

SHIP: AOR-1

DATE: 2/26/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOR-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	28100
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	7590
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	274
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	20
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.12
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	5500
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	6750
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	17753
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	76625

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>AOR-1</u>		DATE: <u>2/26/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOR-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>28100</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>7590</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>1.00</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>274</u>
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	<u>20</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>2</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>5</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>4</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>21.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>1300</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	<u>1.12</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>50340</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>6752</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>17753</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>76625</u>

CALCULATION OF TOWING RESISTANCE

SHIP: AOE-1

DATE: 2/26/75

BY: LC5

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AOE-1
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	73100
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	7570
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	1.00
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	774
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	2.0
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	2
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	5
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	12.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.04
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1300
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	1.12
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	36500
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	36500
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	15300
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	135000

CALCULATION OF TOWING RESISTANCE

SHIP: AGP-1

DATE: 2/24/75

BY: PCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AGP-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>38100</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>7570</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>1.00</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>274</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>20</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>2</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>5</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>27.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.2</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>4700</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>2.16</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>37500</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>35513</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>7512.2</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>103125</u>

AD-A150 941

DEVELOPMENT OF A CALCULATION PROCEDURE FOR THE
DETERMINATION OF TOW RESISTANCE (UNABRIDGED REPORT)(U)
ROSENBLATT (M) AND SON INC NEW YORK APR 76

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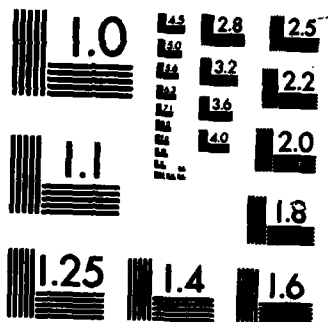
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CALCULATION OF TOWING RESISTANCE

SHIP: Agv-1

DATE: 1-13/75

BY: PCC

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>Agv-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>38100</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>7570</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>1.00</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>377</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>20</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>2</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>5</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>27.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>47500</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>2.46</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>21900</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>55538</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>32422</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>113860</u>

CALCULATION OF TOWING RESISTANCE

SHIP: PCF-1

DATE: 2/26/75

BY: PCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AOE-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>321.00</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>7520</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>1.00</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>174</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>70</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>2</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>5</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>13.38</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>90</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>0.02</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>47.00</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>2.16</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>31200</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>25573</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>1440</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>76013</u>

CALCULATION OF TOWING RESISTANCE

SHIP: PC-1

DATE: 7/26/75

BY: ICS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>PC-1</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>13100</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>7000</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>1.00</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>744</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>70</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>2</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>3</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>13.75</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>90</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>0.02</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>47.000</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>0.06</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>31208</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>36508</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>442</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>74057</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 2/24/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	12.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	1.5
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	2573
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	131
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	22155
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	14045
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	17000
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	62073

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 2/24/75

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	0
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	21.5
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	1.5
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	2572
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	131
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	73465
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	14045
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	17000
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	52272

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	131
14	PROPELLER RESISTANCE $= R_p = 3.394 \times .131 \times (4) \times (4)$	POUNDS	28495
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	14105
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	17000
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	57500

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: EF 1040

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		EF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	12.5
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	59500
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	131
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	29435
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	14115
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	17000
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	59500

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 7/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.86
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	24.86
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	2
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	3430
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	26,112
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	131
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	11,115
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	5796
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	9792
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	27827

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: FF 1040 ESCORT

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	2400
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	1715
4	TOW SPEED, V_{TOW}	KNOTS	5
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	35.85
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	24.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	24.86
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	2
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	3430
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	4.8
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.6
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	26,112
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	131
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	11,115
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	5500
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	9792
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	27542

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>FF 1040 ESCORT</u>		DATE: <u>2/24/76</u>	
		BY: <u>ECS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	2400
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	0
10	RELATIVE WIND SPEED, V_R	KNOTS	10
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	0
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	10
15	R_H/Δ (SEE FIG. 17)	—	7.25
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	7127
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	45255
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (14) \times (14)$	POUNDS	627
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	80777

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>FF 1040 ESCORT</u>		DATE: <u>2/24/76</u>	
		BY: <u>ECS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>FF 1040</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>2400</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>1715</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>131</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>2</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>4</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>0</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>10</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>0</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>7.35</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>3125</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>45755</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>627</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>80777</u>

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 Escort

DATE: 7/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3022
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	131
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.20
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	600
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	3
15	R_H/Δ (SEE FIG. 17)	—	4.2
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	17800
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	31731
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	2368
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	52649

TABLE - 6
CALCULATION OF TOWING RESISTANCE

SHIP: <u>FF 1040</u> <u>ESCAP</u>		DATE: <u>7/24/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>FF 1040</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>3020</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>1715</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>131</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>2</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>4</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>4</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>19.8</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>30</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.20</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>609</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>4.2</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>1780</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>31231</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>8363</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>52694</u>

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 FRONT

DATE: 2/24/76

BY: ECS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>FF 1040</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>3400</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>1715</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>131</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>2</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>4</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>29.5</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>70800</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>1.56</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>6300</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>12230</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (14) \times (14)$	POUNDS	<u>5766</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>94754</u>

CALCULATION OF TOWING RESISTANCE

SHIP: FF 1040 ESCORT

DATE: 2/24/76

BY: RCC

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		FF 1040
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	3400
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	1715
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	8.70
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	121
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	2
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	3
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	4
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	23200
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	1.56
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	6620
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	12236
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (14) \times (14)$	POUNDS	5286
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	44754

TABLE - 6
CALCULATION OF TOWING RESISTANCE

SHIP: <u>FF 1044</u>		DATE: <u>2/24/76</u>	
		BY: <u>ECS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>FF 1044</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>3400</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>1715</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>121</u>
6	CURVE NUMBER FOR HULL RESISTANCE, $R_{H/\Delta}$, (SEE TABLE 7)	—	<u>2</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>3</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>4</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>22.98</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>90</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>0.48</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>20,400</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	$R_{H/\Delta}$ (SEE FIG. 17)	—	<u>1.56</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>6620</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>15,229</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>1677</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>41344</u>

TABLE - 0
CALCULATION OF TOWING RESISTANCE

SHIP: <u>FF 1041</u>		DATE: <u>7/21/76</u>	
		BY: <u>RCS</u>	
ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>FF 1041</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>3400</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>1715</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.70</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>131</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>7</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>2</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>4</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>6</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>22.98</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>90</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>0.43</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>20,410</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>1.56</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>6620</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>15,229</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (19) \times (19)$	POUNDS	<u>1677</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>41,344</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 3/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AF 58</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>17500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>4405</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>21.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>2965</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.3</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>49710</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>106</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>23056</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>12655</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>14260</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>53275</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 53 STORES SHIP

DATE: 3/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AF 53</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>15500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>4405</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>8</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>13.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>21.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>7965</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>2.3</u>
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	<u>1.4</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>49910</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>106</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>23225</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>12635</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>14260</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>53875</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: PCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	2.3
11	SEA STATE CORRECTION FACTOR K_1 , (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	49910
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	106
14	PROPELLER RESISTANCE $= R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	23025
15	HULL RESISTANCE $= (10) \times (2) - (14)$	POUNDS	12625
16	SEA STATE RESISTANCE $= R_s = (12) - (15) - (14)$	POUNDS	14260
17	TOTAL TOW RESISTANCE $= R_T = (9) + (12)$	POUNDS	49910

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	4405
4	TOW SPEED, V_{TOW}	KNOTS	8
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	126.34
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	13.5
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	0
8	WIND PRESSURE P , (SEE GRAPH 1)	LBS/SQ. FT.	0
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	0
10	HYDRODYNAMIC UNIT RESISTANCE r_{H_u} (SEE GRAPH 2)	--	2.3
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	1.4
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	49910
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	106
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	23025
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	12625
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	14260
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	49910

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AF 58</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>15500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>4405</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>0</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>29.5</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.7</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>7489</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.7</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>17360</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>106</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>8994</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>1856</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>6510</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>24849</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AF 58</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>15500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>4405</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>35.86</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>24.86</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>1.1</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>4846</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.7</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>17360</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>106</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>8994</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>1856</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>6510</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>22206</u>

CALCULATION OF TOW RESISTANCE BY METHOD USED IN U.S. NAVY TOWING MANUAL

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AF 58</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE 7)	LONG TONS	<u>15500</u>
3	FRONTAL WINDAGE AREA, A_T	SQ. FT.	<u>4405</u>
4	TOW SPEED, V_{TOW}	KNOTS	<u>5</u>
5	DIRECTION OF TRUE WIND FROM BOW, θ	DEGREES	<u>101.8</u>
6	TRUE WIND VELOCITY, V_{WIND}	KNOTS	<u>24.5</u>
7	WIND VELOCITY COMPONENT $V_T = (4) + [(6) \times \cos (5)]$	KNOTS	<u>-0.01</u>
8	WIND PRESSURE P, (SEE GRAPH 1)	LBS/SQ. FT.	<u>0</u>
9	WIND RESISTANCE, $R_W = (3) \times (8)$	POUNDS	<u>0</u>
10	HYDRODYNAMIC UNIT RESISTANCE r_H , (SEE GRAPH 2)	--	<u>0.7</u>
11	SEA STATE CORRECTION FACTOR K_1 (SEE TABLE 8)	--	<u>1.6</u>
12	HYDRODYNAMIC RESISTANCE $R_H = (2) \times (10) \times (11)$	POUNDS	<u>17360</u>
13	TOTAL PROJECTED AREA OF PROPELLERS, A_p	SQ. FT.	<u>106</u>
14	PROPELLER RESISTANCE = $R_p = 3.394 \times (13) \times (4) \times (4)$	POUNDS	<u>8994</u>
15	HULL RESISTANCE = $(10) \times (2) - (14)$	POUNDS	<u>1856</u>
16	SEA STATE RESISTANCE = $R_s = (12) - (15) - (14)$	POUNDS	<u>6510</u>
17	TOTAL TOW RESISTANCE = $R_T = (9) + (12)$	POUNDS	<u>17360</u>

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		<u>AF 58</u>
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	<u>15500</u>
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	<u>4405</u>
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	<u>0.75</u>
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	<u>106</u>
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	<u>12</u>
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	<u>1</u>
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	<u>8</u>
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	<u>0</u>
10	RELATIVE WIND SPEED, V_R	KNOTS	<u>10</u>
11	RELATIVE WIND DIRECTION, α	DEGREES	<u>0</u>
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	<u>1.0</u>
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	<u>0</u>
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	<u>10</u>
15	R_H/Δ (SEE FIG. 17)	—	<u>3.15</u>
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	<u>61031</u>
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	<u>39612</u>
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	<u>1672</u>
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	<u>102315</u>

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	21.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	2.05
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	39719
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	25352
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	7727
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	74298

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	15500
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	19.82
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.13
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	2.05
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	39719
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	25352
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	7421
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	73992

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	4
10	RELATIVE WIND SPEED, V_R	KNOTS	10.87
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.8
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	1500
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	8
15	R_H/Δ (SEE FIG. 17)	—	2.05
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	39719
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	25352
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	1580
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	68151

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCs

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG TONS	15500
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	29.5
11	RELATIVE WIND DIRECTION, α	DEGREES	0
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.0
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	41,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.83
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	16081
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	9903
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	14548
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	81532

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	15500
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	28.7
11	RELATIVE WIND DIRECTION, α	DEGREES	30
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	1.13
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	41,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.83
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	16081
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	9903
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	15560
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	82544

CALCULATION OF TOWING RESISTANCE

SHIP: AF 58 STORES SHIP

DATE: 2/24/76

BY: RCS

ITEM NO.	DESCRIPTION	UNITS	
1	SHIP CLASS (AE, CVA, ETC.)		AF 58
2	TOW DISPLACEMENT, Δ (SEE TABLE-7)	LONG. TONS	15500
3	FRONTAL WINDAGE AREA, A_T , (SEE TABLE 7)	SQ. FEET	4405
4	WIND DRAG COEFFICIENT, C_w , (SEE TABLE 7)	—	0.75
5	TOTAL PROJECTED AREA OF PROPELLERS, A_p , (SEE TABLE 7)	SQ. FEET	106
6	CURVE NUMBER FOR HULL RESISTANCE, R_H/Δ , (SEE TABLE 7)	—	12
7	CURVE NUMBER FOR WIND FACTOR, K , (SEE TABLE 7)	—	1
8	CURVE NUMBER FOR SEA STATE RESISTANCE, R_s , (SEE TABLE 7)	—	8
9	BEAUFORT NUMBER (WIND) - (SEE TABLE-8)	—	6
10	RELATIVE WIND SPEED, V_R	KNOTS	23.98
11	RELATIVE WIND DIRECTION, α	DEGREES	90
12	HEADING COEFFICIENT K , (SEE FIG. 13-15)	—	0.8
13	SEA STATE RESISTANCE R_s , (SEE FIG. 16)	—	41,000
14	SELECT A TOW SPEED, V_{TOW}	KNOTS	5
15	R_H/Δ (SEE FIG. 17)	—	0.83
16	HULL RESISTANCE = $R_H = (15) \times (2) \times 1.25$	POUNDS	16081
17	PROPELLER RESISTANCE = $R_p = 3.737 \times (5) \times (14) \times (14)$	POUNDS	9903
18	WIND RESISTANCE = $R_w = 0.00506 \times (4) \times (3) \times (12) \times (10) \times (10)$	POUNDS	7690
19	TOTAL TOW RESISTANCE = $R_T = (13) + (16) + (17) + (18)$	POUNDS	74674

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